A QUANTITATIVE DECISION SUPPORT MODEL TO AID SELECTION OF COMBAT AIRCRAFT FORCE MIXES FOR CONTINGENCY DEPLOYMENT

THESIS

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Abstract

Selection of combat aircraft during crisis action planning can be of critical importance. In determining the value of force mixes, it is proposed that one can evaluate extrinsic and intrinsic value separately. Intrinsic value is the designed capability of a weapons platform to accomplish a specified aerospace mission. Extrinsic value is the expected appropriateness of such platforms, given the environmental characteristics in which they must operate. This research develops a decision support tool for planners in determining the extrinsic value of force mixes, which then expedites the selection of best overall force mixes.

The research included: content analysis of official guidance, Critical Decision Methodology interviews, a Delphi study (to define and quantify the factors, and establish a hierarchy and global weights), generation of the Value Focused Thinking decision tool, and establishment of an appropriate representation of the relationship between extrinsic and intrinsic value.

This research provides planners—throughout the USAF—with a decision support tool that objectively compares alternative force packages for specific deployments. This represents a first step toward codifying or formalizing the art of force selection. These results will help reduce the crisis action response timeline, and should lead to more accurate modeling of force mix applicability.

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I. Introduction

Background

Contingency deployment planning is as critical to the United States Air Force's (USAF) wartime mission accomplishment as any task could be. During both deliberate and crisis action planning processes, decision makers must allocate resources and manpower with sufficient strategic and tactical vision to affect total mission accomplishment under conditions of both uncertainty and risk. Limited resources of all types among all of the armed forces significantly constrain decision makers during such planning, and necessitate paradigm-shifting, creative solutions.

The USAF has responded with the Air Expeditionary Force (AEF) concept while simultaneously pursuing initiatives to reduce the resources required for deployment (the deployment *footprint*) and to increase management flexibility with regard to resource allocation [Godfrey, 1998; Looney, 1996]. The AEF concept reflects the Air Force's policy of Global Engagement, in which forces deploy worldwide from the continental United States on short notice rather than maintaining a permanent presence at forward, overseas locations. Additionally, the AEF approach attempts to provide operational units important reconstitution and training periods by allowing for cyclic rotation of the Air Expeditionary Wings (AEW's) to which the units are attached. The AEF concept allows the decision makers visibility of which units are both on tap and available for

deployment. It also generates flexibility in managing scarce resources by virtue of the relative centrality of forces within the continental United States, which can then be projected anywhere in the world.

Enhancing the visibility and flexibility—as well as the response time—of resources in today's planning environment is vital to future USAF mission success. The Defense Advanced Research Projects Agency (DARPA) has spent four years developing a distributed computing architecture that will create a new and improved process for deployment planning for all U.S. military forces. This architecture, known as the Advanced Logistics Project (ALP), has been geared toward total, near instantaneous asset visibility among all Department of Defense (DoD) units. Such real-time visibility will naturally present planners with many options but will also present possibly complicated tradeoffs.

It is the measure of these potential tradeoffs in resources and force mixes to optimal mission accomplishment that constitutes the "value" of a given decision. This is where the Air Force Institute of Technology (AFIT) enters. This research effort is focused in support of AFIT's contribution to the ALP endeavor. AFIT's role in this project is to provide a *value assessment* architecture that provides decision support to contingency planners by identifying utility levels for force mixes (different mixes of fighters and bombers) and their time-phased requirements and respective lift constraints. Overall force mix utility (value) levels may be determined through an appropriate combination and valuation of factors, and those factors can be divided into two general categories: extrinsic and intrinsic. In theory, separate utilities can be established for each category. The extrinsic utility, or value, of a force mix (interchangeably referred to as an

asset set) includes all factors that are *external to* the set's inherent operational capabilities, such as beddown location, fuels support, and political considerations.

Conversely, intrinsic or inherent utility or value is represented by the actual combat capability of a resource. Obviously, the first concern in evaluating a force mix is that the aircraft comprising the set are fully capable of carrying out the designated aerospace combat missions required by the theater commander. Although intrinsic value is critical to force mix selection and would serve as a worthwhile research topic, it is beyond the scope of this research.

Problem Statement

Given that ALP will grant instantaneous visibility of all available resources, while providing an architecture to generate a detailed deployment plan in just minutes versus hours or days, planners at all appropriate echelons will have an opportunity to judge many deployment scenarios at the touch of a computer key. Planners will have expediting tools and complete resource visibility never before seen.

With such information at their fingertips, how then would campaign planners choose from among the competing deployment plans? This research intends to answer that question.

As mentioned, ALP will provide the visibility and the architecture. AFIT's specific contribution to ALP will be the "M-R VAT," the Mission-Resource Value Assessment Tool. The M-R VAT will provide support for *time-phased* decisions that goes beyond current time phased force deployment documents (TPFDD's) and will help

to evaluate operational campaign requirements along a timeline before the deployment occurs. Chapter II provides more information on the ALP and M-R VAT.

The basic premise of both M-R VAT and this supporting research is that campaign planners should identify, strategically and then tactically, the time-phased sortie requirements by specific mission type—before the resource selection process begins. That way, a truer representation of what is needed, where it is needed, and exactly when it is needed, will surface. Only then can fully-informed decisions be made as to which force mixes are most appropriate and present the best value.

To aid decision makers in selection of force mixes, this research proposes a decision model, or tool, that integrates and quantifies all of the *extrinsic* factors that affect force mix selection. It is important to note that campaign planners will judge the *inherent* operational value of force mixes (their absolute mission capability) *separate* from this model, using criteria that are beyond the scope of this research. This research provides one necessary step to aid war planners in selecting the highest value force mixes in the shortest possible time.

However, in accomplishing the goal of this research, it is necessary to establish that both extrinsic and intrinsic factors exist and to clearly define each type. Chapter II addresses these issues.

Research Questions

Central to providing an executable, integrative decision analysis model to enhance the force mix selection efforts of campaign planners, this research addresses the following six questions:

1. Can the factors affecting force mix selection in response to theater crises be clearly categorized as extrinsic and intrinsic, and can these categories be clearly defined?

2. What extrinsic factors are important to campaign planners when selecting aircraft force mixes in response to theater crises?

3. How are these factors quantified, and what are the relationships between them?

4. How should these factors and the relationships between them be modeled?

5. Can the research results be applied USAF-wide?

6. How can the now-quantified *extrinsic* factors be effectively combined with the *intrinsic* factors to develop an overall asset set utility or value?

Methodology

This research involved four broad phases aimed at answering the six research questions. The first phase was comprised of a form of Cognitive Task Analysis interviewing known as Critical Decision Methodology (CDM). These interviews were conducted with 34 campaign planning experts from the Pentagon (HQ USAF), four USAF major commands, the USAF Air Expeditionary Force Center (AEFC), and three USAF academic "schoolhouses." The purpose of the interviews was three fold: to validate the extrinsic factors that had been identified in previous AFIT research (discussed in Chapter II), to identify any factors that had not been previously captured by a decision support model, and to determine appropriate definitions for every factor identified. Post interview content analysis and literature review were the primary tools for extracting the factors. This phase addressed research questions 1, 2 and 5.

The second phase of research consisted of a literature review to determine the most appropriate Decision Analysis technique with which to model this decision situation. This phase addressed research question 4.

The third phase of research was conducted by in-person interviews and e-mail questionnaires, using a modified "Delphi" approach, and was built upon the foundational work of Phase 1. By exploring and defining the relationships between the factors, consistent with expert responses via the Delphi questionnaires, a conceptual map or model of the factors was developed. The completion of Phase 2, due in large part to the diversified expert pool, addressed research question 3 and laid the groundwork for addressing research question 6.

Phase 4 of the research focused on final development of the decision support model and explored the mathematical relationships between the proposed decision support model and the intrinsic value of a candidate force mix (research question 6). Extensive consultation with colleagues performing parallel research and a comprehensive literature review comprised this phase.

Assumptions

The validity of this decision support model is dependent upon the assumption that the USAF theme of Global Engagement does not dramatically change. That is, the USAF currently provides for combat forces to respond to theater crises primarily from stations within the continental United States, on a rotational basis. A dramatic change would most closely approximate a return to the *pre-drawdown* military doctrine of forward basing, in which almost all required active duty forces are already in place in the theaters

of crisis. Such a scenario could lessen or eliminate the positive impact of this decision support model. However, the assumption of a continuing Global Engagement theme is sound, given the end of the cold war and the relative inefficiency of forward basing.

Scope and Limitations

DARPA's ALP initiative encompasses the entire Department of Defense. The ALP will grant streamlined, automated deployment planning capabilities and real-time asset visibility for resources spread among all of the military services. However, the efforts of this research are limited to force mix selection for the United States Air Force only, without regard to other services or other service capabilities. On a highly positive note, this research applies to the entire Air Force rather than being limited to a single theater of operations or a single major command, as was the case with previous research in this area (discussed in Chapter II). The diversity of the expert pool, as well as the phrasing of interview questions, was designed to provide that this research is representative of the Air Force as a whole.

Due to the nature of this research and the fact that key operating instructions and concepts of operations are classified, highly sensitive, or not pertinent to this study, both the research conclusions and the information used are limited to an unclassified level.

Although the focus of this research is to create a decision support model that will aid campaign planners in selecting the best force mixes, the scope is limited to only those *extrinsic* factors that are important to such decisions. *Intrinsic* factors are addressed with respect to their existence, definition, and exclusivity to this model, but are not investigated further. Efforts will be made to mathematically relate or link the *extrinsic*

factors to potential existing *intrinsic* values, but no attention will be given to the identification or development of an intrinsically-oriented decision support model.

Finally, the basic framework for USAF expertise within this research is limited to *current* doctrinal and instructional USAF and Joint publications, and USAF campaign planning experts that are currently active in their respective fields. This scope limitation to present-day expertise and guidance is well-founded, given that doctrine and instruction are necessarily gleaned from past lessons. Furthermore, the experts presently assigned to planning positions or doctrinal/planning schoolhouses are the very individuals who are shaping the direction of contingency planning for the USAF into the near-term future.

Summary

This chapter provides the justification and motivation for developing a decision support model that will significantly aid campaign planners in selecting the best force mixes for contingencies. The critical nature of campaign/deployment planning in today's Air Force is undeniable. This research quantifies the *extrinsic* deployment planning factors and integrates them into an executable decision model that will simplify and streamline this most critical process.

Chapter II discusses deliberate and crisis action planning under the AEF concept as well as the initial extrinsic and intrinsic factors, then provides a thorough background discussion of DARPA, ALP, and the M-R VAT. The chapter also covers the previous research effort that generated an initial collection of extrinsic factors and an executable decision support model. The chapter ends with a review of CDM interviewing, content analysis, and Delphi studies—all of which were used in this research.

Chapter III is a continuation of the literature review that focuses on the background and theory of decision analysis, and reviews a number of candidate decision analysis tools and models, providing the pros and cons by which to measure each tool's suitability to this research problem. The chapter ends with identification of the selected decision analysis technique for this research.

Chapter IV lays out the methodology of this research. It begins with an overview of the research plan, to include the research design, and then covers the three main phases of research in depth.

Chapter V presents the results of each research phase. It goes further in describing the final decision support model, the sensitive analysis, and the justification for the mathematical concepts used.

Chapter VI provides conclusions, as well as discussions about this model's applicability to DARPA, ALP, M-R VAT, and the USAF. Recommendations are made as to how to integrate this model with existing research results and what further research is most appropriate.

II. Literature Review

Introduction

Campaign planning in today's military environment is both challenging and extraordinarily critical, with the decisions of planning experts not only affecting the lives and well being of friendly forces but possibly affecting the final outcome of the conflict itself. In the USAF, a fundamental mission of planners at all echelons is to provide the Joint Air Component Commander and or Theater Commander a set of combat aircraft sufficiently capable of meeting theater air combat requirements. These sets of combat aircraft are referred to throughout this work as *force mixes*. A force mix is defined here as any combination of USAF weapon systems that collectively possesses the inherent capability to meet or exceed the air combat requirements for a specific conflict within a specific theater—as determined by the appropriate campaign planners. This definition is important when noting that planners must select force mixes that are *inherently* capable of accomplishing a given mission. The central theme of this research is that these planners must do so while faced with extremely short time constraints, high stress, and a large number of *extrinsic* factors that compound an already complex decision situation.

This chapter first provides an overview of the current USAF deployment/contingency planning process and addresses the fundamental problem: the need for quick, effective, and efficient force mix selection. It also defines both extrinsic and intrinsic factors, and provides an initial listing of factors for each type—in their broadest forms. The chapter then presents an overview and background of the ALP and the M-R VAT. Together, these sections serve to orient the reader and to establish the importance and support for this research.

The fourth section of the chapter presents a background of a previous research effort that specifically spurred this current investigation. The chapter concludes by discussing the two primary knowledge elicitation techniques used during this study, Delphi and Critical Decision Methodology (CDM).

Deployment Planning Overview

The AEF Perspective on Campaign Planning. Faced with a continuous threat from the Soviet Union and Eastern Bloc during the Cold War, the United States spent half a century building and maintaining a significant number of combat resources and military personnel overseas, primarily in the European and Pacific theaters. Such presence was deemed necessary to counter the sizable force-to-force advantage held by communist nations in these respective regions. Today, with the end of the Cold War, such force-to-force mismatches no longer exist. Although legitimate threats to the national security of the United States have not been eliminated, the single, most central threat has been reduced sufficiently to generate a new way of strategically addressing national defense.

In the United States Air Force (USAF), Global Engagement is the new strategic direction. It is aimed at supporting the country's national interests anywhere in the world, any time, from force pools located primarily within the continental United States (CONUS). The Air Expeditionary Force (AEF) concept has taken hold as the USAF's primary tool in carrying out the potentially formidable tasks presented by the Global Engagement theme—quick regional response from CONUS-based forces, regardless of the nature and extent of the conflict. Explicitly, the USAF is tasked with providing air

and space forces that meet *specific theater requirements* across the *full spectrum of military possibilities* [Cohen, 1998].

Today, the AEF concept is in full force, with the establishment of the AEF Center (under the Air Staff) at Langley Air Force Base, Virginia. The AEF approach cements the USAF change in strategy from forward basing with abundant resources to global engagement with scarcer resources and greater flexibility [Looney, 1996: 5].

Within just 48 hours following an execute order, AEF units are expected to have deployed to the theater and commenced combat air operations. Typically, an AEF unit's force mix consists of 36 aircraft combining Air Superiority, Air Strike, and Suppression of Enemy Air Defense (SEAD) mission capabilities [Godfrey, 1998: 1]. However, such packages can be, and often are, tailored to meet specific requirements. Regardless, an AEF unit is expected to conduct either defensive or offensive air operations independently for the first seven days, in effect *buying time* until reinforcements (if necessary) become available [Godfrey, 1998: 2].

It is easy to see the criticality of proper force mix selection, given the AEF environment. The AEF must respond to crises ranging across the *full spectrum of potential military operations*, and must do so in extremely limited time. Compounding the situation is the fact that individual deployable AEF force mixes may soon be reduced to six-, four-, or two-ship packages rather than the much larger Unit Type Codes (UTCs) by which they now deploy [Petersen, 2000]. UTCs are essentially squadron-sized (or slightly smaller) *force packages* that planners then tailor to suit their individual requirements. They provide for resource justification and accountability and are extremely convenient when planners are pressed for time. Given the current initiatives to

either reduce or eliminate UTCs [Petersen, 2000], timely selection of the best force mixes will become increasingly challenging and potentially overwhelming.

Campaign Planning—The Force Mix Selection. As previously mentioned, force mix selection for response to contingency requirements is the fundamental problem addressed by this research. However, force mix selection is just part of a complicated campaign planning process. The selection of a force mix begins a chain reaction logistics response aimed at getting the desired forces and the necessary support resources to the right place at the right time. Therefore, force mix selection might have the single greatest impact on the size of the deployment footprint and the deployment speed, as well as overall force sustainment over the course of the conflict. Of all campaign planning tasks, force mix selection is of prime importance.

Campaign planners at all levels within the DoD have access to volumes of official publications to guide the planning process. The joint planning environment is where it all begins during times of crisis. Joint operations are those involving cooperation and interplay within theater by more than one US military service. The joint planning process is what makes this possible, and it serves as the solid bridge along the command trail that extends from the National Command Authority (NCA), through the Joint Chiefs of Staff (JCS), to the military services and respective Commanders in Chief (CINCs) of given theaters of operation. Joint planning is a systematic procedure used by relevant commanders to ascertain the best solution for accomplishing assigned mission tasks [JSOG, 1997: para 500].

The Joint Operation Planning and Execution System (JOPES) is the information, command, and control tool that integrates DoD resource and readiness information to

meet the needs of joint planning decision makers. JOPES expedites the development of both options and subsequent operational orders during crisis action planning, and is the primary management tool for the generation and execution of all necessary operations along the crisis response timeline, including mobilization, deployment, employment, sustainment, and redeployment [JSOG, 1997: para 506].

Planners utilizing JOPES have two volumes of Joint Pub 5-03.1, Joint Operation Planning and Execution System, that describe operation of the system. Volume I provides instruction on planning policies and procedures. Volume II deals with formats and guidance. Both volumes are unclassified, and they exhaustively address—from a generalized joint operations perspective—the full spectrum of joint planning under JOPES.

Official guidance for addressing both the planning and the command and control issues during joint-level crisis action planning is contained in Joint Pub 3-56.1, Command and Control of Joint Operations, and Joint Pub 5-00, Doctrine for Planning Joint Operations. Both are unclassified, and both provide broad guidance not limited to JOPES usage.

Clearly, campaign planners have ample joint operations guidance. However, such guidance is not specific to uniquely USAF-oriented operations. Two volumes of Air Force Manual 10-401 serve to supplement joint instructions. Volume I, Operation Plan and Concept Plan Development and Implementation, provides guidance that maintains the necessary joint perspective while focusing on US air power and its proper implementation. Volume II, Planning Formats and Guidance, provides instruction on JOPES utilization to generate such plans. Further, USAF war planners draw directly

from the basic concepts of Air Force doctrine in matching mission requirements to available resources in times of crisis. To this end, all USAF planners keep and maintain copies of Air Force Doctrine Document 1, Basic Air Force Doctrine [AFDD 1, 1997], and Air Force Doctrine Document 2 [AFDD 2, 1998], Organization and Employment of Aerospace Power.

Although comprehensive and thoroughly representative, this listing of publications available to campaign planning experts is by no means exhaustive. It is merely a snap shot of the wealth of information and tools available to decision makers today, and it serves to illustrate the potential complexity of campaign planning and force mix selection. This research depended heavily on content analysis of many sections of these publications, as well as an overview reading of each. However, aside from the identification of extrinsic factors and intrinsic factor categories to be addressed later, these publications will not be discussed in depth.

Although force mix selection is just one part of a complicated planning process that includes use of JOPES and many official publications as guidance, it is indeed this selection of forces that drives the requirements for the entire deployment and employment process. Decision makers need a tool, a decision model, that incorporates both the judgement of seasoned planning experts and the guidance of official publications in order to very quickly and effectively select the best force mixes to meet requirements.

Planning Decision Factors: Extrinsic Versus Intrinsic. It is proposed that the factors to be evaluated in determining the best force mix can be divided into two categories, intrinsic and extrinsic. Because this research is limited to the creation of a

decision model for extrinsic factors only, it is necessary to clearly define both types of factors.

Definition 1: Intrinsic factors represent a weapons platform's fundamental ability to accomplish a specified aerospace mission or tasking [Buzo, 2000: 2], and are limited to determinations of efficacy in a given situation related only to the designated purpose of its design. For example, an A-10 aircraft's fundamental ability is Air-to-Ground Attack; its intrinsic value for such missions is high because Air-to-Ground Attack is the designated purpose of an A-10's design.

Definition 2: Extrinsic factors are situational considerations, external to and independent of the purpose of a weapons platform's design, that affect determination of the appropriateness and subsequent goodness of that weapons platform for a specified mission—given a specific contextual environment that requires evaluation [Buzo, 2000: 2-3]. For example, an A-10 aircraft's extrinsic value, given a situation where the operating location is 2,000 miles from the primary targets and 30mm ammunition is unavailable, might be quite low due to the A-10's lack of speed and need for 30mm ammunition.

Definitions 1 and 2 were refined via interviews with subject matter experts during the early phases of research. Although the final forms are presented here, discussion of their development is reserved for Chapter IV.

Intrinsic and extrinsic factors form a natural, logical separation during the course of crisis action planning (CAP). Given an overarching mission in response to a crisis, planners immediately conceptualize potential force mixes based upon factors related only to the individual weapons platforms' capabilities to accomplish the tasks called for, a sort

of "pie in the sky" wish list of combat forces [Duvall, 2000; 12 AF, 2000]. This early process is more "artwork than science," and leads to course of action (COA) development based initially on the force mixes desired [Duvall, 2000]. This subsequent COA then introduces situational factors and logistical requirements—the extrinsic factors—in accomplishment of various feasibility analyses [12 AF, 2000].

Consider a campaign planner's need to provide a force mix capable of accomplishing air interdiction. Candidate weapons platforms can be considered solely on the basis of their designed capability to accomplish this aerospace mission. The F-15E Strike Eagle is certainly qualified for air interdiction when considered independently of any other situational factors. The A-10A ground attack aircraft is not. The platform's designed capability is thus an intrinsic factor.

In consideration of time limitations and resource constraints, this research is limited to *extrinsic* factors only. However, the question of *intrinsic* value is being investigated by others at AFIT in support of the ALP, concurrently with this research.

Given a weapons platform that is intrinsically capable of accomplishing a desired aerospace mission, the extrinsic factors affecting the situation could determine the overall suitability of the platform. For example, an excessive distance of the staging base from the desired targets may negate the use of the desired platform, even though the platform is intrinsically capable. If the staging base in question is the only available operating location option, then this extrinsic factor would affect the selection of the force mix.

This research posits that extrinsic factors can be quantified and valued independently of intrinsic factors because all extrinsic factors are situational, and any candidate force mix can be weighed against a given situation. However, the relationship

between a situation and its impact on a candidate force mix requires study. One can be evaluated without the other, but final selection of a best force mix cannot occur without a final integration of the two. Hence, force mixes will have separate intrinsic and extrinsic utilities that will induce potential tradeoffs in value that result in an overall value for a given force mix in a given situation.

As the central starting point for determining the decision factors which form the foundation of this research, content analysis was accomplished on Air Force Doctrine Document 2 [AFDD 2, 1998: 76], Air Force Doctrine Document 1 [AFDD 1, 1997: 46-60], Joint Operation Planning and Execution System [JPUB 5-03.1, 1994: P-1 to P-5], and A Decision Support Tool to Aid Campaign Planners in Selecting Combat Aircraft for Theater Crisis [Buzo, 2000: 42]. The content analysis yielded sets of intrinsic and extrinsic decision factors that campaign planners must consider in times of crisis (see Figure 1)

The factors gleaned are broad and general, more probably serving as categories of decision factors rather than factors in and of themselves. Such broadness is desirable at this point because it presents a fundamental starting point. Notice upon examination of Figure 1 that both extrinsic and intrinsic factors or categories are identified. This research focuses, from this point forward, on only the extrinsic factors. Perhaps a number of future studies will be necessary in order to properly address the intrinsic decision factors of campaign planning. Figure 1 presents the initial factors.

EXTRINSIC FACTORS / ISSUES	INTRINSIC FACTORS / ISSUES
Enemy Capability	Counter Air Mission Suitability
International Politics	Counter Land Mission Suitability
Deployment Resources	Counter Sea Mission Suitability
Sustainment Resources	Strategic Attack Suitability
Staging Base Considerations	Special Operations
Location Characteristics	Surveillance Mission Suitability
Host Nation Capabilities	Reconnaissance
Host Nation Support	Combat Search & Rescue Requirements

Figure 1: Extrinsic and intrinsic decision factors/issues

The Advanced Logistics Project and the M-R VAT

The general factors identified in Figure 1 provide a starting point for discussing force mix selection criteria. Crisis action planning for contingency deployments, for both joint operations and within the Air Force, is a complicated task involving a myriad of complex decisions under high pressure situations, often with severe time constraints. The selection of force mixes to best accomplish the mission is the prime prerequisite for development of the overall logistics plan. Errors or miscalculations in the initial selection of force mixes may create undesirable repercussions in the logistics plan development to follow, lending criticality to the importance of force mix selection decision support tools.

The Defense Advanced Research Projects Agency (DARPA) is in its fifth year of developing the Advanced Logistics Project (ALP), a technological approach to significantly reducing the logistics planning process time that could change the face of deployment planning for all military departments [Carrico, 1999]. The ALP will be a "distributed computing architecture that will create a near-real-time deployment planning process for military forces by enabling logistics planners from the US military services to

quickly and efficiently develop and implement a situation-tailored logistics plan" [Carrico, 1999: 1].

The ALP is an automated system that will integrate all logistics missions and organizations, utilizing a single system to expedite seamless planning and execution [Shaneman, 1999: 6]. An "object-oriented design methodology" uses simplified but well-defined components to spur comprehensive logistics management across the full system. These components are the "basic building blocks," known as the ALP clusters, that represent combat units, support units, and command and control responsibilities [Shaneman, 1999: 6]. For the USAF, the ALP contingency process begins when the deployment order is initiated. Clusters for deploying units, in real time, fill the required AEF clusters with forces and resources. The AEF cluster immediately tailors all requirements based on decision rules and sends these requirements to the Logistics Readiness Center (LRC) cluster. The LRC cluster sources all requirements using optimization techniques and submits the results to the US Transportation Command (TRANSCOM) cluster. Finally, the TRANSCOM cluster integrates these requirements with those of the other services' deploying forces, optimizing the sequence and speed of airlift while reducing the deployment footprint [Shaneman, 1999: 7].

The ALP presented a "landmark" demonstration in 1998, building a Level 5 (the most detailed) logistics plan for the US Army's 3rd Infantry Division from their home station through full administrative load onto a ship in port. Using a small set of directives, ALP produced the required high-detail logistics plan in less than one hour [Carrico, 1998: 5].

It is important to note that the demonstration used standard internet bandwidth and medium capability personal computers, and built the detailed plan based on live data from the Joint Total Asset Visibility (JTAV), Global Transportation Network (GTN), and Global Decision Support System (GDSS) databases [Carrico, 1998: 5]. The ALP will quickly provide joint detailed logistics plans, the results of which can then be transmitted instantaneously to all of the critical players to generate significantly reduced deployment timelines.

However, the process as it stands now *begins* with the deployment order. The ALP has not yet attained the ability to expedite selection of the *best* logistics plan from among competing alternatives [Buzo, 2000: 1]. Selection of the best logistics plan cannot occur without beginning the process with selection of the *best force mix*.

Recognizing the logical requirement of having a *best* force mix as input into the ALP architecture, DARPA enlisted the aid of the Air Force Institute of Technology (AFIT). Lieutenant Colonel Alan Johnson and Major Stephen Swartz, both assistant professors at AFIT, seized this tasking in conceptualizing the Mission-Resource Value Assessment Tool (M-R VAT). The M-R VAT will assign relative values to critical resources over time, better coordinating the time-phased arrivals of resources on given days of the contingency with actual requirements for those given days [Swartz, 2000: 1].

The most fundamental concept embraced by the M-R VAT is the *time value of logistics* [Swartz, 2000: 1]. That is, the *value* of a resource *changes* over time as a campaign progresses. Because the nature of the mission changes over the course of a conflict, the value of required combat resources must change to reflect this [Swartz, 1999b: 1]. Existing time phased force deployment documents (TPFDDs) already

prioritize resource movement to theaters, but such prioritization is based on the criticality of combat units rather than the time-phased criticality of resources *within these units*. The M-R VAT shifts this prioritization paradigm. It will go further by decreasing the logistics footprint in the crucial early days of airlift operations by enabling commanders to select the force mixes that possess the best time-phased utility *before* they request resource allocations.

Initialization, Analysis, and Monitoring/Replanning comprise the three phases of the M-R VAT operation, explained by Major Swartz:

> During the Initialization Phase, the M-R VAT elicits critical information from the user and structures the nature of the specific situation to be addressed. The Analysis Phase consists of determining the best set of solutions for the problem, and assisting the decision maker in considering tradeoffs before making the final selections. During Monitoring and Replanning, the system databases are updated as the plan is executed. The decision maker is presented with a running summary of plan execution, and he or she is able to re-solve the problem as the situation changes. [Swartz, 2000: 2]

This research is in direct support of the M-R VAT. Specifically, the extrinsically-centered decision support tool developed here will provide the decision factors to be used by the campaign planner in addressing the specific situation during the M-R VAT Initialization Phase. Furthermore, the decision support tool will provide a scored set of feasible solutions during the M-R VAT Analysis Phase.

The Existing Decision Support Tool for M-R VAT

This research, aimed at developing an extrinsically-oriented decision support model, is a direct follow-on to Lieutenant Christopher Buzo's work, *A Decision Support*

Tool to Aid Campaign Planners in Selecting Combat Aircraft for Theater Crisis [Buzo, 2000].

In his work, Buzo used content analysis of JPUB 5-03.1 and AFDD 2 to establish the minimum, basic set of extrinsic considerations necessary for campaign planning [Buzo, 2000: 42]. He then used modified Cognitive Decision Method (CDM) interviewing techniques to elicit additional extrinsic factors related to campaign planning from 25 USAF subject matter experts [Buzo, 2000: 16-20, 46]. The interviews also served to refine, define, and expand those factors that had been previously identified through content analysis. All of the subject matter experts were USAF officers holding the ranks of Major through Colonel (O-4 through O-6), and were drawn from Air Combat Command, Air Force Central Command, Air University, and Air Staff [Buzo, 2000: 46].

Challenged with developing an executable decision support tool using these extrinsic factors, Buzo investigated two Decision Analysis (DA) models [Buzo, 2000]. His candidate models included Thomas L. Saaty's Analytic Hierarchy Process [Saaty, 1982], and a form of Multi-Attribute Utility Theory (MAUT) that utilizes Value Focused Thinking, developed by Ralph Keeney [Keeney, 1992].

Citing several potential shortcomings with the Analytic Hierarchy Process (AHP), Buzo selected Keeney's Value Focused Thinking (VFT) application of MAUT [Buzo, 2000: 20-21]. Lieutenant Colonel Jack Kloeber, Associate Professor of Operations Research at AFIT, advocated the use of VFT over other Decision Analysis methods and helped to develop the theoretical foundations of Buzo's work. VFT's appeal is that it provides a method for quantifying otherwise *qualified objectives*, rather than *alternatives*, in structuring a decision maker's values—a hierarchical, objectives-oriented approach to

decision making that integrates all of the important considerations [Keeney, 1992; Buzo, 2000: 21]. Both AHP and the VFT application of MAUT are discussed as decision model alternatives in Chapter III.

Having used VFT techniques to establish a hierarchy of factors representing the extrinsic decision objectives of force mix selection, Buzo conducted additional interviews with the subject matter experts to obtain scores, weights, and relationships for and among the factors [Buzo, 2000: 44]. An important consideration is that Buzo concentrated these follow-up VFT model-building efforts on the expertise of USAF Central Command planners, intentionally limiting the scope and applicability of his decision support tool to theater operations in Southwest Asia [Buzo, 2000: 6, 44].

Crisis Action Planning for contingency deployments in the USAF involves *group* decision making. Furthermore, the decentralization of responsibilities and authority among the USAF Major Commands may have resulted in individual sets of *business rules* that are *not* universally applied throughout the USAF. For these reasons, Buzo used a modified Delphi study (comprised of 3 rounds of questionnaires) that generated subject matter expert agreement on the structure, scores, and weights used in his VFT decision support tool [Buzo, 2000: 44, 55-63]. However, only ten of the original 25 subject matter experts participated through the final round of questionnaires [Buzo, 2000: 81].

Buzo's extensive use of Craig W. Kirkwood's *Strategic Decision Making: Multiobjective Decision Analysis with Spreadsheets* [Kirkwood, 1997] enabled him to create a spreadsheet-based, executable decision support tool that quantified and related the extrinsic decision factors that are important to campaign planning. Such a tool holds extreme value in today's military operations planning environment and could be

integrated into the M-R VAT and subsequently linked to the ALP. Buzo's work puts the USAF one step closer to optimal force mix selection and near-instantaneous logistics plan development and execution through ALP and the M-R VAT. This one step sets the stage for further research.

Given a wide range of DA tools, techniques, and models available, Buzo examined the merits of only two [Buzo, 2000:20-21]. This current research improves upon that effort by investigating a number of candidate DA tools, beginning with an overview of the field and a general categorization of techniques.

Additionally, Buzo created a *single* VFT hierarchy using over 20 extrinsic decision factors gleaned from his research [Buzo, 2000: 80, 105-112]. Although VFT may be a desired DA methodology in this arena, the initial research did not investigate the possibility that some factors may not belong within the hierarchy, or may at least be better suited to inclusion within a co-hierarchy or subset that integrates with the main hierarchy. Some of the factors may more appropriately serve as a filter or screen for the main tool. The existence and importance of the factors notwithstanding, it is their place and function within the decision support tool that may be in question. It is important to interject here that the extrinsic categories identified in Figure 1, gleaned from content analysis, are the exact starting categories that had been identified by Buzo.

The mathematical relationships that drive the Buzo decision support tool are drawn almost exclusively from Kirkwood's instruction and represent modified MAUT [Kirkwood, 1997]. The factors and sub-factors are additive. This approach is not inherently flawed. However, the current research effort addresses other potential mathematical relationships, between and among factors and sub-factors, as they might

apply to this specific context. The goal is not to introduce altogether different equations and formulas, rather the goal is to avoid exclusion of other mathematical functions that might enhance model performance.

Another area of potential improvement is the subject matter expert pool itself. The Buzo model was built upon the expertise of representatives from just two major commands, one schoolhouse, and the Air Staff. Furthermore, the actual scores and weights of factors were decided by experts from just the Air Force Central Command [Buzo, 2000: 44]. This was the intended scope of Buzo's work, and he does not claim universal applicability to the entire USAF. However, the goal of this current research is just that—universal application for the USAF. To that end, the subject matter pool is larger and represents the four operational major commands (within CONUS), two schoolhouses, and the Air Staff.

This literature review has provided an overview of crisis action campaign planning and illustrated its criticality to USAF operations. It has also given an overview of the ALP and the M-R VAT, the driving forces behind this research. The preceding section discussed the original extrinsically-oriented decision support tool that was developed to meet the needs of M-R VAT and ALP. Next is a discussion of the knowledge elicitation techniques used for this *current* research.

Eliciting Knowledge: Interviewing/CDM, Content Analysis, and Delphi

<u>Interviewing/CDM and Content Analysis</u>. The Critical Decision Method (CDM) of semi-structured interviewing was developed in 1989 by Klein, Calderwood, and MacGregor. It is an expert decision and judgement centered approach to the Cognitive

Task Analysis (CTA) methodology [Buzo, 2000: 16], a methodology that enhances the study of non-observable skills and expert thinking [Seamster, 1997: 25].

CDM goes beyond traditional CTA in that it is a retrospective and introspective interviewing approach that applies cognitive probes to the critical decision points that require expert-level decisions or judgements [Klein et al, 1994: 464].

The processes of making decisions and solving problems on the level of force mix selection are complex and highly cognitive tasks that require considerable skills. They are the processes that actually drive the motor behaviors that have been the subject of traditional task analyses in the past [Seamster, 1997: 78]. The important issues to this research are the previous experiences of subject matter experts and their expert responses to (and their lessons learned from) critical decision making opportunities, not just the motor tasks or structurally imposed behaviors. Hence, CDM, with its emphasis on retrospective cognitive responses, is ideally suited to this research.

In conducting CDM interviewing, the interviewer is tasked with eliciting comprehensive job information from the respondent. This is best accomplished in a semi-structured environment in which the interviewer uses his or her specific knowledge of the information needed to guide the respondent to appropriate personal reference points. The respondent is asked to relay his or her personal experience, given the now developed reference point that involves critical decision making opportunities.

The interviewer uses the situational reference point to probe decision making opportunities, specific to the subject matter expert's personal experience. The challenge is to remain on subject, with the interviewer getting the respondent to answer the questions posed [Interview Research Manual, 1976: 15]. In dealing with incomplete or

inappropriate responses, the interviewer repeats the question, exhibits expectant pause, repeats the respondent's reply, asks a neutral question, or asks outright for clarification [Interview Research Manual, 1976: 15-16].

Questions might arise as to the reliability and validity of information gleaned from CDM interviewing to obtain extrinsic decision factors for crisis action campaign planning. However, some experts clearly advocate the process. According to Canter, Brown, and Groat, "Research would be more effective if procedures allowed the interviewees to express their own view of the issues at hand, in their own way, whilst still providing information that is structured enough for systematic analysis and reporting" [Canter et al, 1985: 83].

The combination of CDM interviewing and content analysis, when done properly, provide for relatively sound reliability and validity. According to Brenner, Brown, and Canter, the processes of content analysis and multidimensional scaling (done in this research via decision analysis) make it possible to develop systematic and quantitative summaries of data that "would not have been amenable to analysis in the past, when such data might have been dismissed as 'too qualitative.' These data can now form the basis of research activity" [Brenner et al, 1985: 1]. Open-ended, largely unstructured research material should not impose "unnatural restraints" on a researcher's analysis [Mostyn, 1985: 115]. The researcher's purpose is to systematically identify the specific elements of communication so that conversion into scientific data can be objectively accomplished [Mostyn, 1985: 117].

This research probes the experiences of subject matter experts using CDM interviewing and content analysis in order to develop an exhaustive listing of extrinsic

decision factors necessary to consider during the force mix selection portion of crisis action planning. Buzo's work on the initial decision support tool followed the same early process [Buzo, 2000]. Elicitation using CDM interviewing is a sound approach to gathering the extrinsic factors necessary to build a decision support tool. Content analysis of the interviews, as well as the official guidance provided for deployment planning, is the intermediate step in gathering and quantifying the factors. Final quantification of factors involves the application of DA techniques, discussed at length in Chapters III and IV.

The Delphi Study. Modified Delphi techniques comprised the preferred method for gaining a consensus of this current decision support tool from among the selected campaign planning experts. Linstone and Turoff define the Delphi technique as "structured communication that allows a group of individuals, as a whole, deal with a complex problem" [Linstone and Turoff, 1975: 3]. Norman Dalkey, one of the originators of the Delphi method, states that the rationale for the use of the technique is to obtain the intuitive insights of experts and to use their judgement as systematically as one can [Adler, 1996: 4]. In order to pool the opinions and expertise of *individuals* within a group into a *central theme* or direction, Delphi techniques allow feedback of individual contributions of knowledge, provide assessment of the group judgement or view, allow individuals to then revise their views in light of other views or a developing central theme, and provide for anonymity among individual participants [Linstone and Turoff, 1975: 3].

What the Delphi technique offers is what is specifically required in this research situation: access to the opinions and judgements of subject matter experts, controlled

feedback to refine these judgements, and a necessary measure of anonymity to assure honest responses that are free from the pressures to conform to group dynamics. The latter point is particularly important in a military setting. In group dynamics, a dominant individual can often influence the opinions of others [Brown, 1968: 2-3]. The effects of individual dominance can be amplified by the clear rank structure within the military, leading subordinates to outwardly concur with the opinions of their supervisors even though they may privately disagree. Delphi techniques eliminate this effect because all responses are anonymous [Brown, 1968: 3].

Linstone and Turoff provide several reasons for using the Delphi method. The first is when the problem cannot be addressed with "precise analytical techniques," but is better suited to the *collection* of individual subjective judgements [Linstone and Turoff, 1975: 4]. Given the need for wide-ranging expertise on decision making during campaign planning, this reason certainly applies to this research. The second reason offered is when more experts are needed than can interact in a committee-type exchange or face-to-face group interview [Linstone and Turoff, 1975: 4]. Again, this applies to this research because campaign planning experts are currently *on duty* in their respective critical fields, and spread among a number of offices and agencies across the United States. The third reason, similar to the second reason in substance and applicability here, is when the time and cost are sufficiently high to preclude frequent group meetings [Linstone and Turoff, 1975: 4]. The final reason to use the Delphi method is to avoid group domination by quantity (majority), personality, or position [Linstone and Turoff, 1975: 4]. Again, given the clear rank structure and disciplined superior-subordinate relationships in the military, this fourth reason is especially applicable to this research.

Having established the suitability of the Delphi method for this research, it is necessary to discuss the process.

Generally put, the Delphi method is used to collect and distill the knowledge of subject matter experts by using controlled opinion feedback that is interspersed within a series of questionnaires [Adler, 1996: 3]. The Delphi technique is usually executed in 3-4 rounds that may or may not involve the two general phases of exploration and evaluation [Turoff, 1975: 89]. Given a generalized problem with no central theories in which neither the issues nor the solutions are clear, an exploration phase can approximate the start of ungrounded research. However, a study in which theory discovery is not a goal and in which issues are clearly identified need only use an evaluation phase, bypassing an unnecessary exploration.

The first round of Delphi is "seeded" with an initial range of options (in general, but particularly in this research), but allows individuals almost absolute freedom to expand or alter the list [Turoff, 1975: 89]. During this round, group members come to understand the goals of the study, as well as the terminology and taxonomy, and they examine the subject issues to validate their personal competency levels with regard to the subject and direction of the study.

The responses of the experts to the Delphi's first round begin the *controlled feedback* process that is an important aspect of this technique. The controlled feedback process reduces extraneous or redundant material that might otherwise obscure the more significant material offered by the experts [Dalkey, 1967: 3]. The researcher filters the extraneous or irrelevant information and summarizes the important contributions, re-submitting the results to the expert group. This second round provides experts with

points of view they may not have considered, while also providing all of the group experts a compilation of ideas that may begin to resemble either a central them or a divergence in schools of thought [Dalkey, 1968: 4].

How does this work? Each member must justify their responses (anonymously), which are then made available to all other group members. Through Round 2 and subsequent iterations of the process, experts begin to take into account "considerations they might through inadvertence have neglected, and to give due weight to factors they were inclined to dismiss as unimportant at first thought" [Brown, 1968: 2-7].

The number of rounds used to accomplish a Delphi study is not necessarily a good measure of the technique's success. Furthermore, the reaching of a consensus or central theme is also not a measure of Delphi success. Turoff explains some approaches that could go far in reducing the number of necessary Delphi rounds, beginning with the researcher's dedication of considerable time and effort to the formulation of *obvious issues* that are clearly exhibited [Turoff, 1975: 89]. A second approach is to ask the expert participants for both their positions on an item and their *underlying assumptions*—in the very first round of the study [Turoff, 1975: 89]. These approaches could result in a 2-3 round Delphi study that holds extreme value to the researcher. As for reaching a consensus, it is not necessary and may not be desirable in some situations. Delphi studies can result in *divergence* of ideas, the polarization of experts into two camps. This in itself is valuable insight into the applicable issues that could make a given Delphi study quite fruitful. However, in the case of this research aimed at creating a decision support tool that is universally applicable to the entire USAF, a group consensus was desired.

The Delphi method is a well-tested and appropriate approach to efforts geared toward generating a consensus [Linstone and Turoff, 1975: 75]. In the case of this research, the extrinsic decision factors affecting force mix selection were already gleaned through CDM interviewing and content analysis. It was the determination of the best *relationships* of these factors *within* the candidate decision support tool that required a method of access to individual expertise and judgements that had not yet been, and could not be, provided for by basic research interviewing. In this light, the Delphi technique was the most appropriate method.

Having established the background for this research and the elicitation methods used, Chapter III discusses the Decision Analysis field and the selection of the most appropriate Decision Analysis technique for this decision situation.

III. Determining the Best Decision Analysis Model

Decision Analysis

This chapter discusses the progression of decision analysis applications from their basest forms to more complex approaches that deal with uncertainty, risk, sequentiality, and multiple criteria and objectives.

Structuring a Decision. According to Derek W. Bunn, decision analysis (DA) is conventionally understood to fall within the larger study of the entire management field, with a primary focus on choosing a sound alternative from among competing potential alternatives using a perspective that is essentially methodological [Bunn, 1984: 1].

A fundamental philosophy of DA is the breaking down of a decision into its component parts. An otherwise overwhelmingly complex problem can then be astutely analyzed piece-by-piece, with the subsequent re-composition of the problem providing insights and recommendations that allow the decision maker to attack the overall situation with more confidence and competence [Bunn, 1984: 4, and Clemen, 1990: 4-5]. The pattern of relationships developed by breaking a decision problem down come to constitute a particular *decision model* [Bunn, 1984: 4].

The situational features that can make a decision problem sufficiently complex to warrant DA techniques include uncertainty, multiple objectives, multiple options, and sequentiality [Bunn, 1984: 4]. These features are discussed in greater detail periodically throughout the chapter.

In first approaching a decision situation, decision makers often begin with an elementary framework, "taught throughout private industry, schools, and even the Girl

Scouts," that includes 1) defining the problem 2) gathering facts and making assumptions 3) developing possible solutions 4) analyzing and comparing possible solutions 5) selecting the best solution [Lemire, 1991: 5]. This framework constitutes a decision model in its most basic form, and serves as the sequence flow for DA processes.

Robert T. Clemen refines and expands upon this basic DA sequence. In his book, Making Hard Decisions, Clemen describes a step-by-step process that also begins with *identifying the problem* [Clemen, 1990: 5]. His second step is the identification of *objectives and alternatives*. He refers to the third and fourth steps, *decomposing and modeling the problem* and *choosing the best alternative*, respectively, as the "modeling and solution [which] form the heart of most textbooks on decision analysis" [Clemen, 1990: 6-7]. While many discussions of the decision making process stop at Clemen's fourth step, Clemen adds more. *Sensitivity analysis* should be performed once a solution is selected, and this should be followed by a determination of whether *further analysis* might be necessary before implementing the proposed solution [Clemen, 1990: 7].

Figure 2 depicts a flow chart representation of Clemen's decision analysis process. The process serves as a sequential guide to analyzing decision problems in almost any managerial arena. However, such flow chart guides are woefully inadequate in that they leave the decision maker to rely on his or her own capabilities, experience, education, and resources in the accomplishment of the steps of the process. More advanced DA models provide many of those tools so essential to decision makers in addressing complex decisions.

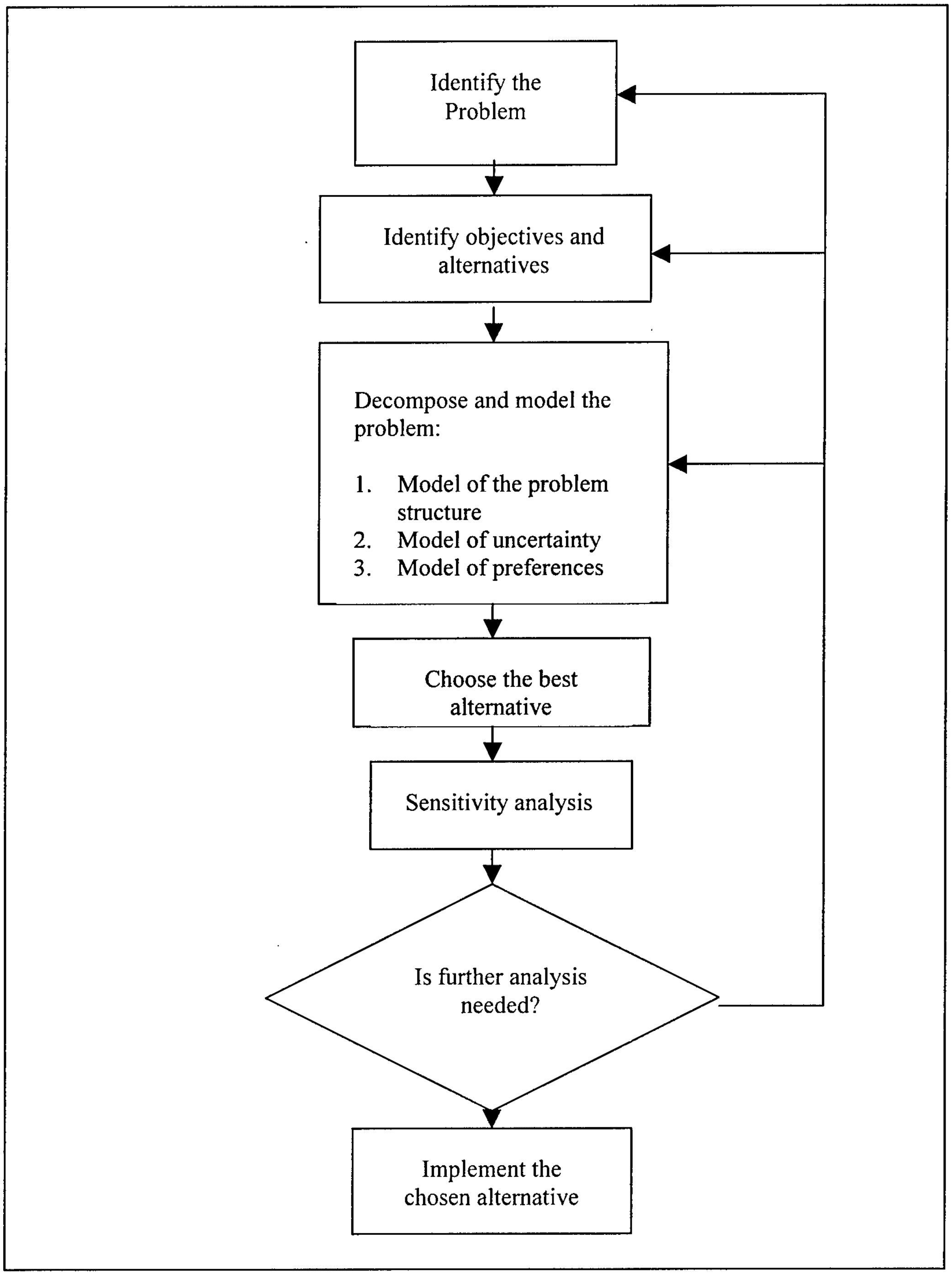


Figure 2: Decision analysis process flow chart

The framework established by DA flow charts like that shown in Figure 2 serve as the foundation for more comprehensive decision support tools that subsequently break decision situations into their component parts.

Howard and Matheson, in their book The Principles and Applications of Decision Analysis, address the "heart of…decision analysis" (Clemen's *decomposing and modeling the problem* and *choosing the best alternative*) with an *analysis* flow diagram that forms the basis for creating a decision support tool [Howard and Matheson, 1983: 26]. Figure 3 presents this approach.

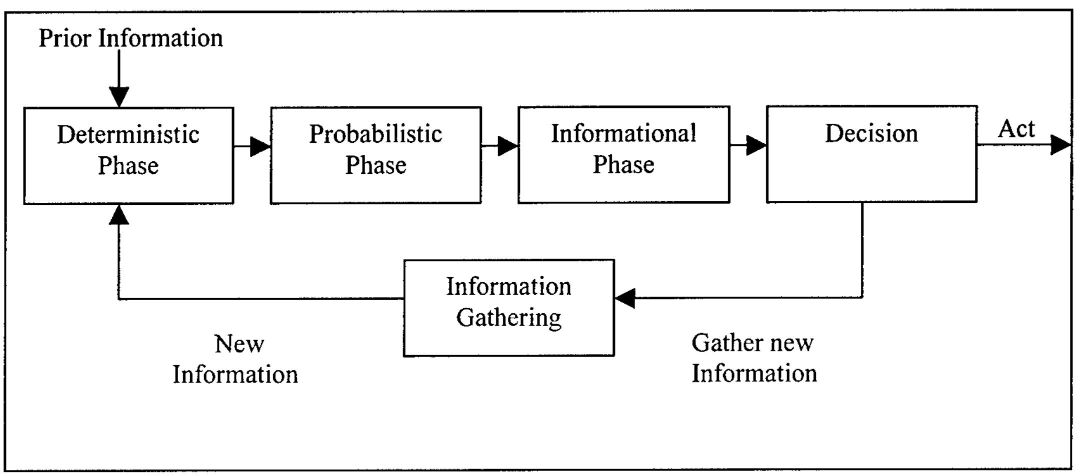


Figure 3: The decision analysis cycle

This DA cycle provides for the structuring and analysis of those decision problems that are sufficiently complex to warrant decomposition; namely, those that include probabilities, uncertainty, risk, and sequentiality—as illustrated by the phases shown in Figure 3.

Extending Decision Structures: *Probability, Uncertainty* and *Risk*. Decision trees and influence diagrams provide decision makers with useful means for decomposing decision problems that have multiple steps (sequential) and that involve measures of probability and uncertainty.

Influence diagrams help decision makers conceptualize all of the elements of a situation, providing simple graphical representations of which decisions are to be considered, what uncertain events will influence intermediate and final outcomes, and what values are to be placed on potential outcomes [Clemen, 1990: 34].

Decision trees go further than influence diagrams, representing the specific decision points in a sequential process while providing *choice* branches for the decision maker to consider and *probability* branches that represent chance outcomes (events) that might follow these choices [Clemen, 1990: 49]. "A decision tree represents the possible unfolding of events in temporal order" [Heckerman et al, 1995: 2]. Together, influence diagrams and decision trees comprise DA models that serve as tools for decision makers. However, many decisions require substantially greater decomposition or an altogether different approach. Often, these models are used only for setting the basic structural foundation for addressing uncertainty and risk. One group of authors explains the place of uncertainty in decision making:

> ...ambiguity or probabilism intervening among elements of the task environment. Such uncertainty is regarded as intrinsic within the judgement or decision problem; it cannot (at the time the judgement or decision is made, at least) be eliminated, and it exists independently of the judge or decision maker's (or the analyst's) representation of the problem. [Hammond et al, 1980: 193]

Using decision trees as their maps, decision makers can apply *expected values* and *expected utilities* to the elements of their respective situations in order to effectively account for uncertainty and risk.

Expected value refers to the value of an uncertain outcome, computed as the probability-weighted average of all possible outcomes [Clemen, 1990: 178]. For example, if only two outcomes are possible, x and y, and each is weighted at a probability of .5, then the x value is multiplied by .5 and the y value is multiplied by .5 and the total is summed. Therefore, if x equals 100 units and y equals 200 units, then the expected value of the uncertain outcome would be .5(100) + .5(200) = 150 units.

A decision maker's attitude toward *risk* in the face of such uncertainty is necessarily important to the development of a realistic decision support tool, and is most often captured with an *expected utility function*. Utility functions are computed using the decision maker's *points of indifference* concerning potential outcomes, and can identify the decision maker as either risk averse or risk seeking [Clemen, 1990: 376-377].

Decision makers can create decision trees that utilize expected values and expected utilities, using branches of decision nodes to correspond to alternatives and branches of chance nodes to correspond to possible states of individual variables [Heckerman et al, 1995: 2]. This alone can sufficiently decompose many complex decision situations, involving uncertainty, risk, and sequentiality, into points of analysis that can generate highly logical decisions. Perhaps Judith Lemire says it most succinctly:

> One approach to uncertainty is the expected value theory. In this case, one can calculate the expected value of the lottery by multiplying each outcome by the probability of it occurring and then summing the results. Without accounting for risk, an individual should be indifferent to the lottery and the certain receipt of the expected value of that lottery. Many of us, however, display risk aversion, where

> we prefer the certainty. Some individuals are risk prone, where the game itself has value. [Lemire, 1991: 26]

Often, the construction of decision trees that represent uncertainty, risk, and all the choice and chance points in a sequential decision situation can become quite complex. However, such models can still fall short of addressing all of the potential complexities of many decision situations. These additional complexities take the form of *multiple criteria* and *multiple objectives*.

Multiple Criteria/Objective Decision Structures. Decision situations approach their most extreme complexities when they *combine* uncertainty and multiple criteria [Lemire, 1991: 8-9]. Decisions lacking certain information are difficult because of potentially misapplied probabilities and complications in pinpointing risk attitudes. Furthermore, such decisions can have negative results despite the soundness of the process [Lemire, 1991: 8]. Multiple objective decisions can add significantly to this difficulty in that they must often compare "apples to oranges" in considering possibly conflicting goals [Lemire, 1991: 8].

Derek W. Bunn quotes Milan Zeleny, "It has become more and more difficult to see the world around us in a unidimensional way and to use only a single criterion when judging what we see" [Bunn, 1984: 82]. Multiple objectives introduce complexities that can be quite challenging, such as in a situation where a combination of factors has an overall synergistic value that is attained by the *peaking of all* of the factors (far outweighing the *sum* of the individual factors), or in a situation where simultaneous success for all of the objectives is not necessary in order to optimize overall success

[Clemen, 1990: 474]. Multiple objectives are fast becoming the norm in DA. Bunn points out:

> ...many decisions in the public sector appear to involve payoff assessments in more than just monetary values. Siting a nuclear power plant, for example, involves issues of safety, health, environment, and reliability as well as cost. We must therefore look at decision criteria that are multi-dimensional, that can cope with the many conflicting objectives with which decision makers are sometimes faced. [Bunn, 1984: 82]

There exist numerous approaches to dealing with multiple objectives and criteria, including the Kepner-Tregoe method and Multi-Attribute Utility Theory (MAUT), both of which are discussed later in this chapter.

The progression of decision situations and DA techniques from simple to complex is presented in this section only to provide the setting for creating a decision support tool for force mix selection during USAF crisis action campaign planning. This situation most certainly involves the evaluation of multiple criteria. It is important to note, however, that such force mix selection is limited to a *single decision* of which asset set to deploy given a particular *state of nature* at a *discrete point in time*. Therefore, this decision support model need not allow for sequential decision making. A decision tree format is neither required nor appropriate.

Classifying the DA Approaches

This section discusses the general theories of decision making and some of the general classes of models used in DA. Although this literature review is thorough, it is limited and is by no means *exhaustive* of the subject. DA is a growing field of study,

with literally thousands of works on the subject, of which the review of all is beyond the scope of this research.

General Theories. The models, tools, and even the basic theories surrounding the science of decision analysis can be centered either *prescriptively* or *descriptively*—or in combination of both. Prescriptive approaches are also referred to as *rational* or *normative*, telling decision makers *how to* accomplish their task. Descriptive approaches, as the name implies, describe the *processes* of decision making [Oxenfeldt et al, 1978: v-vi]. This research requires the development of a *prescriptive* decision support tool that will aid campaign planners in quickly and effectively choosing force mixes in times of crises. Much of the *descriptive* requirements of such decision making are already provided in training and ample USAF and DoD instructions. However, the descriptive approach is mentioned here because *descriptive versus prescriptive* is the initial dividing point in establishing the classes of DA methods.

According to Oxenfeldt et al, writings on decision making and analysis differ by two fundamental orientations: The mathematical and statistical orientation that constitutes *statistical decision theory*, and the cognitive decision functioning that constitutes *psychological decision theory* [Oxenfeldt et al, 1978: vii].

Hammond, McClelland, and Mumpower, in their book Human Judgement and Decision Making, provide six general theoretical approaches to the study of decision making: Decision Theory, Behavioral Decision Theory, Psychological Decision Theory, Social Judgement Theory, Information Integration Theory, and Attribution Theory. According to the authors, the first three approaches are seated in economics, while the last three are rooted in psychology [Hammond et al, 1980: 9].

Decision Theory (as specifically described and limited here by Hammond et al), is that work most closely associated with Ralph Keeney and Howard Raiffa, and is concerned with choosing among alternatives with multiple attributes [Hammond et al, 1980: 10]. The parameters of choosing one alternative over another are the probability of the occurrence of the alternative and the expected utility to the decision maker [Hammond et al, 1980: 9], placing this approach under the statistical decision theory umbrella of Oxenfeldt et al.

Behavioral Decision Theory is based upon the central idea of human decision making falling short of true rationality. This approach *describes* the less than optimal behavior of the decision maker [Hammond et al, 1980: 10]. It is a descriptive approach that falls within the economics sphere but not necessarily within statistical decision theory.

Psychological Decision Theory moves one step beyond description of human decision making and moves toward explanation and prediction of decision behavior [Hammond et al, 1980: 10]. It does not, however, *prescribe* action or behavior.

Social Judgement Theory emphasizes the interaction between environment and cognitive systems, having its origins in the field of perception [Hammond et al, 1980: 10-11]. Once again, its study is descriptive in nature and clearly falls under the psychological decision theory umbrella.

The second purely psychological approach (fifth approach overall) is Information Integration Theory. "IIT emphasizes and provides for the analysis of the cognitive integration of multiple pieces of information that are measured subjectively, and for which subjective importance is also measured" [Hammond et al, 1980: 12]. This theory

deals with the situational "cognitive algebra" employed, such as the averaging of factor values in some cases and the multiplying of factor values in other cases [Hammond et al, 1980: 12]. Although this approach is descriptive in nature, it clearly has the potential to prescribe. However, the approach falls under descriptive psychological decision theory.

Finally, Attribution Theory studies causal attribution under the "psychology of common sense," directly addressing the tension between common sense and refined knowledge [Hammond et al, 1980: 12]. Simply, this approach addresses the question of "when will a person rather than circumstances be blamed" [Hammomd et al, 1980: 12].

Jon Doyle, of the Massachusetts Institute of Technology, provides another grouping of decision making theories. He refers to rational decision making as "choosing among alternatives in a way that 'properly' accords with the preferences and beliefs of an individual decision maker or those of a group making a joint decision" [Doyle, 1998: 1]. The subject is developed under six general theories: Decision Theory, Decision Analysis, Game Theory, Political Theory, Psychology, and Economics [Doyle, 1998:1].

Doyle discusses Decision Theory and Decision Analysis interchangeably. Game Theory is sequential by nature, involving premeditated, strategic actions and cognitively contrived responses, and so is not applicable to this research. Political Theory, Psychology, and Economics are not expounded upon by Doyle [Doyle, 1998] and are considered here as descriptive schools concerning decision making; they necessarily cross over to statistical decision theory when attempting prescription.

Illustration of the basic separation of classes and general theories of decision making is important to this research in developing the most appropriately structured and oriented decision support tool in aiding campaign planners.

Force mix selection decisions require *prescriptive* tools that fall within *statistical decision theory.* Theories and studies concerned with describing the psychology of decision making offer little value within the scope of this thesis. The remainder of this chapter discusses methods and models that fall within statistical decision theory, the most appropriate candidates for this research problem.

Classes of DA Methods. The classes of DA methods are not always exclusive. Review of the previous section will show that some models can fall under several theoretical umbrellas. Operations research and psychology are the primary fields of study concerned with DA, and DA methods overlap between the two fields. Figure 4 provides some examples to illustrate this relationship [Klimack, 2000].

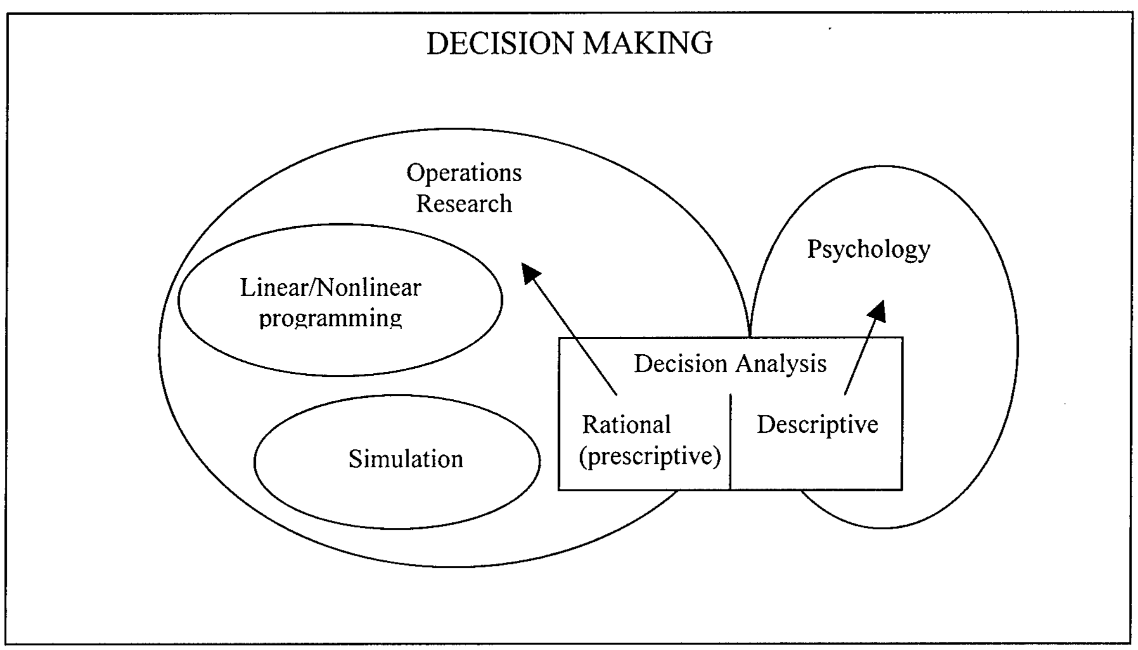


Figure 4: Sample of decision making approaches

Having already established the need in the USAF for a prescriptive (rational), *statistical decision theory*-based decision support tool for campaign planners in selecting force mixes, the reader can readily grasp the sphere of influence this research falls under by reviewing Figure 4. Some examples of rational and descriptive DA methodologies are shown in Figure 5.

Methodologies

Rational (Prescriptive)	Descriptive
Multi-Attribute Utility Theory	Psychological Decision Theory
Analytical Hierarchy Process	Social Judgement Theory
Multi-objective Linear Programming	Prospect Theory

Figure 5: Rational and prescriptive DA methodologies

Michael R. Klein and Leif B. Methlie, in Knowledge-Based Decision Support Systems, offer what might be the most easily discernable break down of DA methods within respective fields [Klein and Methlie, 1990]. Interestingly, they illustrate differentiated groupings of techniques within individual fields of study, and then show a natural convergence of all towards a common master product—a complete knowledge-based decision support system [Klein and Methlie, 1990: 6]. Figure 6, borrowed from the Klein and Methlie text, illustrates perfectly this grouping of methods within disciplines. Notice that, according to Klein and Methlie, only *prescriptive* theories lead to decision support systems (the right side heading at the top of the figure), and a decision support system is what this research strives to create.

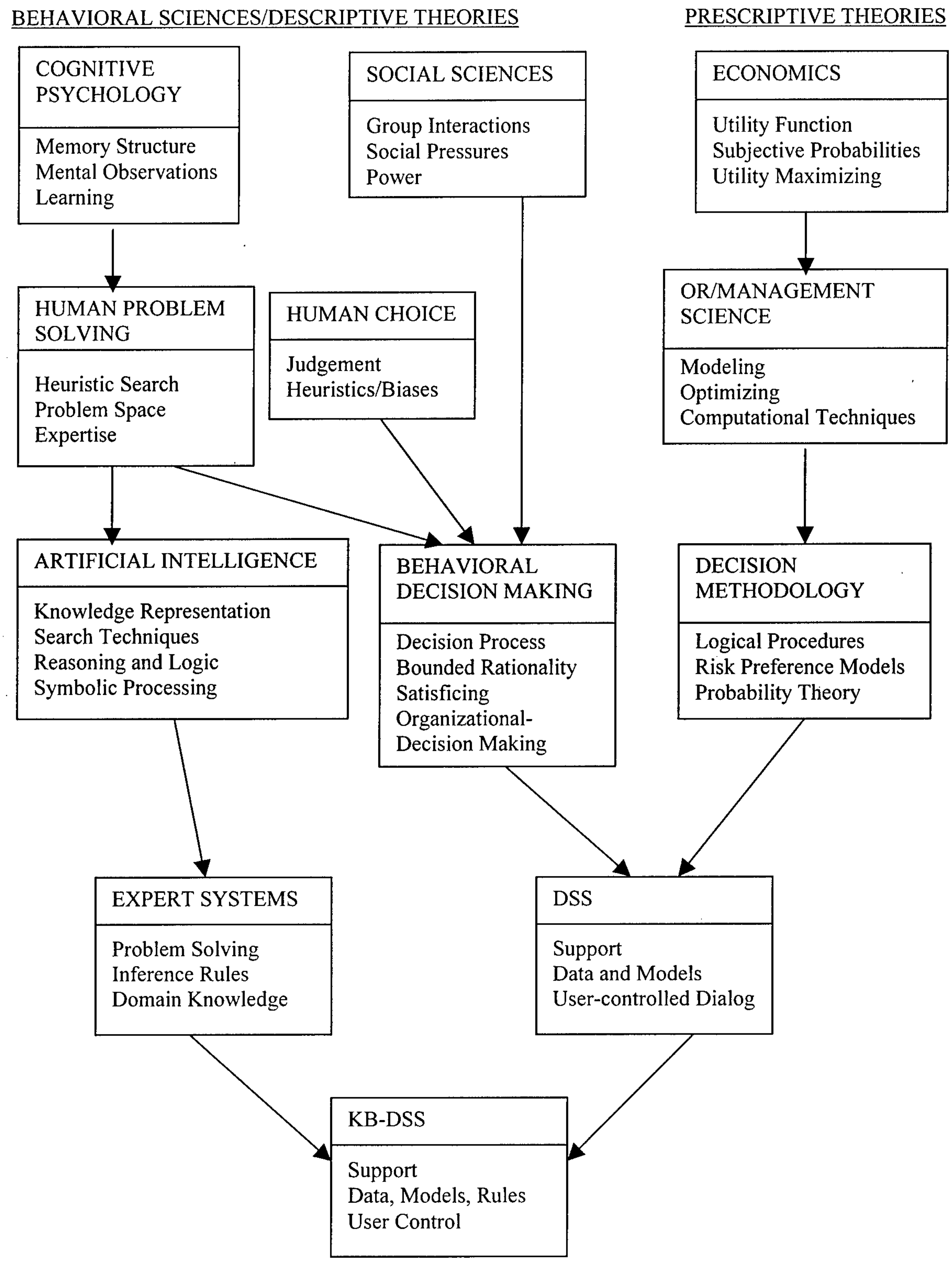


Figure 6: The scientific background of DA and support systems

In Figure 6, the acronym *DSS* stands for "decision support system," and *KB-DSS* stands for "knowledge-based decision support system." This research strives to create a decision support tool for campaign planners using techniques described along the *right side* of Figure 6, namely *utility* (or value) *functions*, *maximizing*, *modeling*, and *optimizing*, among others.

With earlier sections having provided ample discussion of simple-to-complex DA situations and some of the general theories in the field, the right side of Figure 6 clearly narrows the direction of this thesis in satisfying research questions 3 and 4. This is vitally important because much of this entire thesis effort is the search for the *most appropriate* method for modeling the situation.

Specific Approaches. There are many candidate DA methods for modeling this particular decision situation. The most appropriate method must be more than simply the most convenient, the simplest, or the easiest to use. Conversely, it need not be the most complex nor the most novel. It must simply be the *most appropriate* for the problem of force mix selection during crisis action campaign planning in the USAF.

Initially, two economics-rooted decision making methods, the zero-sum technique and the mixed strategy game (and game theory in general), are discarded as candidates for this research. These techniques use the concepts of changing states of nature, sequentially-oriented decision structures, and competitor's actions in defining logical "moves" for the decision maker [Filippi and Nelson, 1984: 26]. Later discussion addresses the characteristics of *this* decision situation that disqualify these concepts as candidate models.

Expected value and expected utility (utility theory) were touched upon earlier. Utility theory has undeniable applicability to this decision situation in that potential decision makers in this case possess expertise that is highly subjective in nature and their decisions will necessarily involve subjective factors. Jon Doyle states, "Though the notions of preference and optimal choice have qualitative foundations, most practical treatments of decision theory represent preference orders by means of numerical utility functions" [Doyle, 1998: 3]. Utility theory, on the surface, is certainly a viable candidate for this decision situation, given this researcher's goal of optimizing force mix selection. Note the following discourse:

> The principle of maximizing expected utility has long been established as the guide to making rational decisions (von Neumann and Morgenstern 1947; Savage 1954; Luce and Raiffa 1957). It rests on two components: probabilities for representing our uncertainty about the situation, and utilities for representing our preferences. [Chajewska and Koller, 1999: 1].

Despite their advantages in converting human judgement and preference into quantitative mathematical measures, utility functions can be problematic. The process of *acquiring* a utility function from an individual decision maker is not sufficiently understood by many analysts, and "there are no experts to ask about the structure" because every person's utility function may be quite different [Chajewska and Koller, 1999: 1]. Moreover, the elicitation process is cognitively difficult, error prone, and often time consuming [Chajewska and Koller, 1999: 1].

Another drawback to basic utility functions is that their elicitation takes decision makers away from reality and into the world of hypothetical lotteries [Goodwin and Wright, 1991: 83]. A decision maker's attitude towards risk may be quite different, given

a *real* situation, than that presented in the utility function that had been elicited. Even if this is not the case, utility functions can result in contradictory decisions as evidenced by the "Allais's paradox" put forward in 1953, in which the existence of a *certain* outcome among probable outcomes creates decisions that are inconsistent with the established expected utility [Goodwin and Wright, 1991: 84-85].

Nonetheless, utility theory is especially valuable in its application in advanced forms such as Multi-objective Linear Programming (MOLP) and Multi-Attribute Utility Theory (MAUT). MOLP and MAUT serve as the two major theoretical approaches to dealing with multiple criteria decision situations [Fuller and Carlsson, 1996: 140]. Basic, or single attribute, utility theory is not applicable to this research because this decision situation involves a number of potential attributes or criteria and an almost infinite number of alternatives. However, both MOLP and MAUT surface as highly viable candidate models in this case, as *extensions* of single attribute utility theory that encompass *multiple* attributes, criteria, and objectives.

This chapter's discussion of decision making theory and different DA methods can now be focused clearly on *multi-criteria models* under the *Operations Research* umbrella of approaches to DA. In addition to MOLP and MAUT, there are many methods for addressing multiple criteria, some of which might be quite appropriate for this decision situation.

Jack Kloeber, a former associate professor at the Air Force Institute of Technology, provides a break down of some common multi-attribute decision analysis techniques, presented in Table 1 [Kloeber, 1992: 16].

Table 1: Breakdown of multiple attribute decision making tools

CHARACTERISTICS	SAWM	MAUT	MLR	TOPSIS	AHP
Requires linearity of response	Yes	No	Yes	No	No
Independence of alternatives required	Yes	No	Yes	Yes	No
Easy to do sensitivity analysis	Yes	No/Yes	Yes	No	Yes
Rank reversal possible	No	No	No	Yes	Yes
Criteria importance determined within the model	No	Yes (VFT)	Yes	No	Yes
Scale of final rankings of alternatives	Ordinal Unknown	Interval Ordinal	Interval	Unknown Ordinal	Unknown
Requirements to build the model	Criteria Weights Raw values	Entire utility functions for all	Past data and Ratings of results	Criteria weights and ranges	Pairwise comparison of criteria
Time intensive?	No	Yes	No	No	Sometimes
Past data required?	No	No	Yes	No	No
Cognitively plausible?	w/right weights, simple problems	Yes, for simple problems	No	No	No
Importance of user judgement	None	Extremely important	None	None	Very important
Scaling problems	Yes	No	Yes	No	No
Consistently and easily combines different criteria	No	Yes	No	No	Yes?
Prescriptive or Descriptive?	Prescript.	Prescript.	Descript.	Prescript.	Prescript.

Table 1 includes the Simple Additive Weighting Method (SAWM), MAUT with VFT (value focused thinking), Multiple Linear Regression (MLR), Distance from Ideal (TOPSIS for example), and the Analytic Hierarchy Process (AHP). This listing is certainly not exhaustive. Other multi-criteria approaches include the Kepner-Tregoe Method (discussed later), the Candidate/Critique approach (of Linden et al, also discussed later), and Multi-objective Linear Programming (MOLP).

While the approaches presented by Kloeber in Table 1 are limited, the left column of his table presents the distinct characteristics, of *any* candidate DA approach, that are necessarily addressed in determining the *most appropriate* decision support tool for this

decision situation. Comparing the characteristics of various DA methods to the requirements of this decision situation generates a final set of viable candidate DA models.

Characteristics of This Decision Problem. Campaign planners in today's USAF require a decision support tool that captures *all* of the relevant extrinsic factors and combines them into a quantitatively-oriented aid to evaluating candidate force mixes quickly and efficiently, with little end-user input or cognitive deliberation. Force mix selection during crisis action planning is a highly critical process that equates to a non-repetitive, executive-level decision of possibly overwhelming magnitude.

Force mix selection is a non-sequential decision process that involves multiple criteria and requires a prescriptive (rational) support tool. The individual *values* or *utilities* of the extrinsic factors that affect force mix selection are *not* necessarily linear [Buzo, 2000]. What's more, user judgement is extremely important in this case because it is the expertise of the *most knowledgeable campaign planners* in the USAF today that should be incorporated into any support tool that hopes to produce the *best* options for campaign planners to choose from.

Because of the criticality of the decisions to be made, this decision situation demands that the importance of all criteria be determined *within* the support tool, and that rank reversals among different criteria are *not* possible (discussed in greater detail later).

To recap, the requirements of this decision situation are: 1) the model must be prescriptive, 2) it must account for multiple attributes, 3) it must provide for non-linear criteria values, 4) user judgement is extremely important, 5) criteria importance must be determined within the model, 6) rank reversals cannot be allowed.

Inappropriate Methods. Before addressing those *multiple criteria* DA techniques that are not appropriate for this situation, a quick review of other disqualified methods is in order. Decision trees and game trees are not appropriate because they require sequentially-oriented decision structures and/or known probabilities for chance occurrences, notwithstanding their potentially intractable compositions if many criteria are evaluated. Prakash Shenoy states:

> ...valuation networks are more appropriate representations than decision trees and game trees for symmetric or almost symmetric decision problems involving *many variables* (italics added) since it is practically intractable to either represent or solve such problems using either decision or game trees. [Shenoy, 1996: 2].

Also excluded as candidates are the zero-sum game, the mixed strategy game, game theory in general, and Bayesian Decision Criteria. Bayesian statistical theory allows for decisions based upon the introduction of new information that creates conditional probabilities [Bunn, 1984: 113-121]. More specifically, Bayes' Theorem allows for revision of *initial* probabilities to *posterior* probabilities, given the results of either a previous decision or an experiment [Hill et al, 1981: 143]. Even allowing for *non-sequential* decision making based upon numerous chance occurrences for which there exists any number of conditional probabilities, this decision situation involves no such chance occurrences within the decision process itself.

Obviously, single attribute utility theory is also disqualified. However, utility theory in its expanded forms (i.e. MAUT) remains in consideration.

As for multiple criteria DA methods, the single additive weighting method (SAWM), while easily applied and understood by decision makers, is disqualified as a

candidate model. Its most important disqualifying characteristics are that it requires linear value measurements for criteria, it provides no method for evaluating the relative importance of criteria within the model, and it does not provide an avenue for converting expert user judgement [Kloeber, 1992: 16].

Multiple linear regression (MLR) is likewise inappropriate. MLR also requires linear values for criteria. More importantly, it is a *descriptive* model that requires past data to generate results rather than the expert judgement of qualified decision makers, making it absolutely inappropriate for a decision support tool that attempts to use expert judgement in its formulation [Kloeber, 1992: 16].

Distance from Ideal (TOPSIS) does not meet the requirements of this decision situation because it likewise does not use expert judgement in its computations. Additionally, it provides no measure of the relative importance of criteria within the model while allowing for rank reversal among criteria (the importance of which is discussed later) [Kloeber, 1992: 16].

<u>Methods Considered</u>. The multi-attribute DA method selected to create the decision support tool for this research must provide an avenue for quantifying the *value* that campaign planners in the USAF place on each of the *individual extrinsic factors* affecting force mix selection. This is necessary to provide for computing the overall *worth* of any candidate force mix—the overriding goal of the MR-VAT and this research. The primary challenge of creating a decision support tool for force mix selection is quantifying the multiple values and worth assessments of the decision makers. James R. Miller III states:

> The concept of worth is a *property* of human beings. It is part of their conscious perceptual apparatus. Human beings may *formulate* notions of worth by observing external objects and activities and by considering situational circumstances; and they may *impute* or *project* these notions, once formulated, onto the external objects and activities being assessed; but the real locus of worth remains within the subjective minds of human decision-makers.
> [Miller, 1970: 14].

Miller claims that "any assessment of worth is *by definition* a subjective process" [Miller, 1970: 14]. This researcher agrees. What is required is a decision support tool capable of quantifying this subjectivity and doing so for multiple attributes.

The chosen multi-attribute method must also allow for the integration of all factors into an overall value that can be maximized according to the decision maker's preferences. In common practice, decision makers often examine only parts of their overall decision situations. They compare (A) to (B) only on price, for example, under the assumption of *ceteris paribus* (other things being equal), often sub-optimizing the overall solution [Hill et al, 1981: 108-109]. *Ceteris paribus* is a "very handy methodological simplification" but one that should be limited to piece-meal construction of an overall, integrative matrix or model [Hill et al, 1981: 109-113].

Five multi-attribute DA techniques stood out as candidates for this decision situation. Each is discussed in detail in upcoming sections. The Kepner-Tregoe approach is the first method considered and is perhaps the simplest. It warrants consideration because it specifically addresses multiple criteria of highly subjective value in the making of decisions. It provides for the rank ordering and weighting of "wants" and a *go/no go* standard for "musts" [Filippi and Nelson, 1984: 81].

The second method discussed is the Candidate/Critique approach in which an automated problem solver interactively presents *candidate* solutions to an end-user who *critiques* those solutions in accordance with his or her values [Linden et al, 1997: 67].

The third approach discussed is decision optimization via Multi-objective Linear Programming (MOLP) methods.

The fourth approach is the Analytic Hierarchy Process introduced by Thomas L. Saaty in 1971. This method provides a means for decisions to be made on complex issues by simplifying "our natural decision-making processes" [Saaty, 1982: 5]. The method serves to capture multiple attributes and to assign quantified values to subjective judgements.

Finally, Multi-attribute Utility Theory (MAUT) utilizing Value Focused Thinking (VFT) is examined. With VFT, *utility* functions are replaced by *value* functions, with a decision maker's values formed hierarchically in the model. Hereafter, MAUT with VFT is referred to as simply VFT.

The Kepner-Tregoe Method

The Kepner-Tregoe method was introduced by Charles H. Kepner and Benjamin B. Tregoe in 1965 as part of their firm's professional problem solving and decision making curriculum [Kepner and Tregoe, 1965: v-vi]. While the method is somewhat dated and surprisingly simple by modern DA standards, it nonetheless possesses intuitive merit in dealing with highly subjective, multi-attribute decision situations.

In a 1984 thesis, A Heuristic Approach to Decision-Making for the Purchase of Acquisition Data, David Filippi and Richard Nelson claimed that "the only suitable

technique which utilizes both subjective criteria and the subjective ratings of those criteria is the Kepner-Tregoe approach" [Filippi and Nelson, 1984: 28]. While such a statement is in error given the work of Keeney, Raiffa, Saaty and others, it does serve to illustrate the usefulness of such an approach to the decision situation at hand.

The Kepner-Tregoe approach is based upon seven concepts of decision making [Kepner and Tregoe, 1965:46-48]:

1. Establish the *objectives* of the decision
2. Determine the relative *importance* of the objectives
3. Develop *alternative actions*
4. *Evaluate* these potential *alternatives* against the established objectives
5. Select a *tentative decision* (choice that best achieves the objectives)
6. Explore this tentative decision for possible *adverse consequences*
7. If this decision becomes final, *control the effects* of the adverse consequences with preventative planning

The procedure for accomplishing the Kepner-Tregoe method follows these seven concepts almost exactly. The decision maker first establishes his or her objectives. Determining the relative importance of these objectives begins with a separation of them into "MUST" and "WANT" categories. A MUST objective is one that must be met and cannot be compromised. A WANT objective is one that can generate the best possible performance from a decision, but which can be bargained [Kepner and Tregoe, 1965: 48].

The MUST objectives are placed at the top as *go/no go* standards. The WANT objectives are then rank-ordered and given relative weights, either as multiples of the lowest-ranked objective or on a scale of 1 to 10 [Kepner-Tregoe, 1965: 48].

The decision maker then develops alternative actions and evaluates them against the MUST and WANT objectives. Obviously, an alternative that does not meet all of the MUST objectives is discarded. The decision maker then *values* (scores) the surviving alternatives subjectively against each WANT objective using a scale of 1 to 10 or 1 to 100, with each alternative's value multiplied by the weight of the corresponding WANT objective. These products are then summed to produce an overall score for each alternative [Kepner-Tregoe, 1965: 46-50].

The highest scoring alternative becomes the tentative solution. The decision maker is not done there. He or she must then brainstorm potential adverse consequences for implementing the tentative solution. These consequences are given "probabilities" of occurring from 1 to 10 (odd, but the scoring system requires that the probabilities be scored at greater than 1) and the decision maker again subjectively evaluates the *value* of each (negative impact) on a scale of 1 to 10 [Kepner-Tregoe, 1965: 198-199]. These values are summed and the total is subtracted from the original overall score for the alternative. Of course, this may reduce the tentative solution's value and result in a different alternative becoming the tentative solution, and the process is repeated.

The final step is to plan for the adverse consequences and implement preventative measures that may mitigate their effects. Figure 7 provides an example of the Kepner-Tregoe scoring method. In the figure, notice that the campaign planner is evaluating two candidate force mixes, Mix A and Mix B, each with a distinct set of fighter and bomber aircraft. The MUST and WANT objectives are comprised of *extrinsic* force mix selection factors.

		Mix A		Mix B	
MUST Objectives	Weight	Rating	Score	Rating	Score
Host Nation Allow Assets In?	N/A	N/A	**Go**	N/A	**Go**
Runway Length and Width Sufficient at Loc.?	N/A	N/A	**Go**	N/A	**Go**

		Mix A		Mix B	
WANT Objectives	Weight	Rating	Score	Rating	Score
Enemy ISR Capability	9.6	10	**96**	7	**70**
POL Storage Capacity	8.7	7	**60.9**	9	**78.3**
Distance from Mission Targets	7.8	6	**46.8**	8	**62.4**
Ability to Re-Supply	6.9	7	**48.3**	9	**62.1**
		Total Score:	**252**		**272.8**

Figure 7: The Kepner-Tregoe scoring method

Independent of potential adverse circumstances related to the decision that must be quantified as mentioned earlier, the campaign planner would select Mix B using the example shown in Figure 7. Notice that the Kepner-Tregoe method provides for decision makers to establish weights for the WANT objectives *prior to* assessing the value that each alternative has against each objective. The method allows for an infinite number of alternatives to then be valued against an existing model (i.e. mixes C, D, and F in the example).

This method is well suited to the decision situation at hand. It provides for quantifying otherwise subjective decision factors and for doing so for multiple criteria. Furthermore, the development of the rank-ordering and weighting of the MUST and WANT objectives can be accomplished using the expert judgement of campaign planners

across the entire USAF. However, the ratings provided by the decision maker in valuing each alternative against each objective must be done independent of this USAF-wide expertise, during crisis action planning at the very time the decision must be made. A better decision support tool would allow the pool of representative USAF experts to develop the *value of the alternatives* (against the objectives) beforehand, along with the rankings and weights of the objectives. That would lend more consistency to results.

The primary goal of this thesis is to develop a decision support tool that will enable selection of *best possible* force mixes. With the Kepner-Tregoe method, such a support tool could approach this goal, but would not reasonably assure its attainment. Why? Because the end-using decision maker inputs every value of every alternative in complete subjectivity. With Kepner-Tregoe, consistency could be almost nonexistent. The method could present significant sub-optimizations if a given campaign planner lacked the knowledge and experience to judge alternatives against objectives at the highest level possible. This researcher posits that the highest level possible is that expertise provided by a pool of the most expert campaign planners. Additionally, the end-using decision maker—even if the most qualified in his or her profession—may require considerable time and cognitive exertion in valuing the alternatives at the very moment when time is critical. Such a situation runs contrary to the goals of this decision support tool.

The Kepner-Tregoe method is a marvelous approach when the end-using decision maker understands the alternatives and objectives better than anyone else, or when that decision maker is solely responsible for every aspect of the decision situation. For USAF campaign planning, we need something more.

The Candidate/Critique Method

The key concept of the Candidate/Critique model of problem solving is that it is *interactive*. Decision makers input their subjective preferences via an iterative process with an automated decision support tool. This method is one of the latest developments in operations research, with Thomas and Fischer (1996), McCalla et al (1996), and Mukhopadhyay and Mostafa (1996), all paving the way by introducing decision support/information filtering models that automatically infer user preferences via multiple iterations driven internally [Linden et al, 1997: 67]. Actual Candidate/Critique methodology goes one step further.

The natural extension of the approach is that of Linden et al. They are developing an automated decision support system utilizing a manual user model counterpart. Their system provides for progressive dialogue whereby the automated problem solver provides available options to the user and the user provides information as to the quality of those options [Linden et al, 1997: 68]. A key is that the system's user model improves over time and ultimately results in a solution that is acceptable to the decision maker [Linden et al, 1997: 68]. Figure 8 provides an example of a basic problem solving dialogue between a travel agent and a client.

Figure 8 was borrowed from the Linden et al paper, Interactive Assessment of User Preference Models: The Automated Travel Assistant [Linden et al, 1997: 68]. Throughout the progressive interaction, the agent learns more and more about the client's subjective preferences such as his desire to fly on American Airlines and his moderate price sensitivity. An important consideration is that the client's preferences involve somewhat complicated tradeoffs between the flight, airline, and departure times that

could become intractable if modeled ahead of time within the automated decision tool [Linden et al 1997: 68].

Client: "I want to fly from Seattle to Newark next Tuesday afternoon."
Agent: "I've got a United flight at 3:30pm for $500 and an American flight at 12:30pm for $520."
Client: "I can't leave before 3:00pm but I do prefer American."
Agent: "I have another American flight through Denver at 4:00pm for $530."
Client: "That's pretty expensive. I'd be willing to go on a later flight or another airline if it'd be much cheaper."
Agent: "The cheapest flight is USAir at 8:00pm for $490."
Client: "In that case, the American flight is fine."

Figure 8: Example dialogue between a travel agent and client.

The Candidate/Critique method aims to replicate this iterative process between agent and client as closely as possible, with an automated problem solving tool that does not calculate subjective values ahead of time—it calculates them from the user model inputs as they occur [Linden et al, 1997: 69].

> Although we do not attempt to implement a natural language interface, we would still like to capture the essence of this problem-solving process. In these problems, the system has access to a large dataset and the problem-solving methods unavailable to the user. The user has access to preference information not directly available to the system. The basic mode of interaction is iterative and cooperative, where the system and the user both attempt to convey only relevant knowledge. The problem is considered solved when the user is presented with a solution he considers acceptable. [Linden et al, 1997: 69]

Two significant drawbacks exist with the Candidate/Critique method in its current early stage. First, the argument that computing subjective values ahead of time can become intractable is countered by the argument that any such computations that are in

fact manageable *should be* included ahead of time. This reduces or eliminates the possibility of involving the end-using decision maker in an intractable process. Especially in cases such as force mix selection during crisis action planning, whereby the expert opinions of seasoned campaign planners across the entire USAF can present a level of expertise not attainable by any one expert. Interestingly, the Candidate/Critique system uses MAUT as its underlying user model, differing from traditional MAUT only in that the system creates value functions at the time a decision is being made. While this gives a level of reflexive support to the subjective values of end-using decision makers that rivals, or exceeds, that of the Kepner-Tregoe method, it leaves out the valuable group expertise, could lead to significant inconsistencies, and could prove most time-consuming just when time is of the essence.

The potential time-consuming property of the Candidate/Critique approach is its second major drawback. Depending upon the problem domain, preferences could "amount to an explicit total order over all candidate solutions" and the subjective critiques could become "pairwise comparisons between two candidates where nothing more could be inferred about the user's preference ordering" [Linden et al, 1997: 70]. The authors admit that the model could be "intractable and unrealistic in its full generality" [Linden et al, 1997: 70]. They suggest its use for graphical layout problems, internet searches, merchandise selection, and airline reservation selection [Linden et al 1997: 69]. Force mix selection, on the other hand, involves a myriad of extrinsic and intrinsic factors that combine with an almost unlimited number of potential fighter and bomber force mix combinations, making Candidate/Critique unsuitable for now.

The Candidate/Critique method has tremendous potential in the campaign planning arena but not with respect to the extrinsically-oriented decision support tool researched here. Extrinsic factors, and intrinsic factors via future research, should be identified, valued, and structured into a viable model in support of M-R VAT. This would be necessary whether or not Candidate/Critique were used, since that method requires MAUT development anyway (a complete DA technique in its own right).

However, the vision for M-R VAT is that it become a decision support model that integrates intrinsic and extrinsic decision factors along with corresponding resource lift requirements (and availability) and actual combat sortie projections. Given a situation of evaluating just these few subjective tradeoffs, the Candidate/Critique approach could prove most valuable as the user interface for M-R VAT. As for the extrinsic model proposed by this thesis, Candidate/Critique is an inappropriate method.

Multi-Objective Linear Programming

Multi-objective linear programming (MOLP) is an extension of basic linear programming that addresses the problem of competing objectives in a decision situation. Linear programming is essentially a solution optimizing technique developed in the 1940's by George B. Dantzig and originally known as the "programming of interdependent activities in a linear structure" [Lee, 1972: 15]. Prior to addressing MOLP, it is important to discuss the structure of basic linear programs.

Put simply, linear programming addresses situations in which a *decision* must be made, restrictions or *constraints* are placed upon the available alternatives, and a primary goal or *objective* is present [Ragsdale, 1998: 17-18]. With linear programming, it must

be possible to express all of the functions as a linear combination or weighted sum of the variables, producing the general form shown in Figure 9 [Ragsdale, 1998: 23].

MAX (or MIN): $c_1X_1 + c_2X_2 + ... + c_nX_n$

Subject to:

$$a_{11}X_1 + a_{12}X_2 + ... + a_{1n}X_n \leq b_1$$
$$a_{k1}X_1 + a_{k2}X_2 + ... + a_{kn}X_n \geq b_k$$
$$a_{m1}X_1 + a_{m2}X_2 + ... + a_{mn}X_n = b_n$$
$$X_j \geq 0 \text{ for } j = 1, 2 \ldots n$$

Where:

c_i = coefficients of the objective function (such as dollars)

X_j = decision variables (alternatives to be changed)

a_{ij} = numeric coefficient in the *i*th constraint for variable X_j

b_i = constraints

Figure 9: Basic linear program formula

For single overriding objectives, computer programs such as Excel Solver can utilize formulas like that shown above to generate optimal solutions to the decision problem. Since linear optimization models assume that the "values of all the relevant parameters are known with certainty," the DA problem solving efforts concerning this technique are prominently focused on finding the most efficient *search technique* [Joshi, 1980: 311].

MOLP eliminates the limitation that a decision situation have just one overriding objective; it provides a realistic and robust approach to dealing with multiple competing objectives so long as linearity of the attributes of the situation is maintained [Anderson et al, 1974; Joshi, 1980; Lee, 1972; Ragsdale, 1998].

The difference with MOLP is that *multiple objective functions* (such as the MAX or MIN function in Figure 9) can be used to generate a new *overall* objective function. For example, if a decision maker desired three *competing* successful outcomes, each of these outcomes (objectives) would be solved *independently* of the other two but within the same model, with all constraints enforced for each iteration, providing three *separate optimal solutions*. These would serve as the *best known* possible outcomes for each objective, giving the decision maker valuable reference points for his or her judgement of the final solution. More importantly, these three optimal solutions would then become *target values* in the formulation of the new overall objective function.

With target values, the decision maker need only minimize the maximum percent deviation ("MINIMAX") of each objective from its target value [Ragsdale, 1998: 276-286]. This method also allows for *weighting* the percent deviations to reflect the decision maker's preferences with regards to each objective's importance. The formula to generate target values would look much like that in Figure 9 but with three objective functions rather than one. The final formula's objective function, using target values, would look similar to Figure 10.

In Figure 10, the w_i's refer to the individual weights assigned as the measure of importance the decision maker gives each objective, and the T_i's refer to the target values obtained by optimizing each objective separately as mentioned in the previous paragraph. By implementing a computer-generated search technique (such as branch and bound) to generate the lowest possible *maximum weighted percent deviation* among the three objectives, MOLP presents a remarkable approach to solving multi-criteria problems that far exceeds the cognitively-generated solutions of human decision makers.

MIN: $w_1\left(\frac{(a_1X_1 + a_2X_2) - T_1}{T_1}\right) + w_2\left(\frac{(a_3X_1 + a_4X_2) - T_2}{T_2}\right) + w_3\left(\frac{(a_5X_1 + a_6X_2) - T_3}{T_3}\right)$

OR, to produce the *lowest maximum* deviation, use the MINIMAX variable Q such that:

MIN: Q

Subject to (additional constraints now):

$$\left.\begin{array}{l} w_1\left(\frac{(a_1X_1 + a_2X_2) - T_1}{T_1}\right) \\ w_2\left(\frac{(a_3X_1 + a_4X_2) - T_2}{T_2}\right) \\ w_3\left(\frac{(a_5X_1 + a_6X_2) - T_3}{T_3}\right) \end{array}\right. \quad each \leq \text{Q}$$

Figure 10: MOLP objective functions

In using MOLP, a decision maker can be assured that no better feasible solution exists, given that the constraints are sound and accurate, the weights for the objectives are accurate representations of the decision maker's values, and all of the attributes are linear [Joshi, 1980; Keeney and Raiffa, 1976].

However, the development of weights for each objective could become an exhaustively iterative process for the decision maker as he or she adjusts the weights to explore solutions that do not necessarily occur at the corner points of the feasible region [Ragsdale, 1998: 287].

Another approach to MOLP is offered by Madhukar Joshi, and provides for the computer's search technique to generate the weights [Joshi, 1980, 341]. In his approach,

each of K objective functions is given a weighting coefficient without an expressed aspiration level, such that:

$$Z_k = \sum_{j=1}^{n} C_{kj} X_j \text{ for k = 1, 2, ... , K}$$

With nonnegative weights, $W_1, W_2, ... W_k$, such that:

$$W_1 + W_2 + ... + W_k = 1$$

Then the MOLP is formulated as:

MAX: $$Z = \sum_{k=1}^{K} W_k Z_k = \sum_{k=1}^{K} W_k (\sum_{j=1}^{n} C_{kj} X_j)$$

Subject to:
$$\sum_{j=1}^{n} a_{ij} X_j \leq (= or \geq) b_i, \text{i = 1,2,...,m}$$
$$X_j \geq 0, \text{ j = 1,2,...,n}$$
$$W_k \geq 0, \text{ k = 1,2,...,K}$$
$$\sum_{k=1}^{K} W_k = 1$$

With this formulation, the user or decision maker does not specify the objective weights, this is left to the computer [Joshi, 1980: 341]. Therefore, decision maker input as to the relative importance of the competing objectives is nonexistent! It would seem that MOLP gives us a situation whereby the decision maker either manipulates weights in the search for solutions or leaves the importance of each objective up to the optimization of the computer. However, this statement is only partially true.

According to Robert Fuller and Christer Carlsson, a number of MOLP models involve utility theory-based tradeoffs between objectives and include integer and stochastic variables, as well as methods using "ideal" and "reference" points [Fuller and

Carlsson, 1996: 140]. These would seem to better capture human subjectivity without the measure of interactive play required of traditional MOLP. This research posits that such models blur the distinction between MOLP and more developed multi-criteria decision making (MCDM) techniques such as MAUT and VFT. In fact, Fuller and Carlsson group both MAUT and MOLP under the MCDM umbrella and imply that MOLP becomes a true MCDM technique when it is interactive and involves utility functions [Fuller and Carlsson, 1996: 139-140]. This crosses the threshold of linearity of attributes and addresses non-linear criteria, more closely approximating MAUT. MAUT (using VFT) is discussed later as the fifth candidate approach to this decision situation.

Horn et al address MOLP: "Historically, multiple objectives (i.e., attributes or criteria) have been combined ad hoc to form a scalar objective function, usually through a linear combination (weighted sum) of the multiple attributes, or by turning objectives into constraints" [Horn et al, 1993: 1]. Such would tend the model toward the requirement for *linearity* of its attributes.

Some of the problems associated with linearity requirements are presented by Madhukar Joshi:

> ...let us pause to discuss the meaning of linearity. An LP problem has three properties: proportionality, additivity, and divisibility. Proportionality implies that the amount of resources used up in performing an activity is proportional to the value of the corresponding action variable. It also implies that the payoff associated with that activity is proportional to the level of that activity. ...The [linear] model does not allow for possible fatigue [for example] at the end of the day, nor does it consider the increase in workers' speed due to familiarity. [Joshi, 1980: 321-322]

Additivity, another condition of linearity, necessitates that the objective function's value is obtained by *adding* the contributions of each activity. This implies that sales of

one item, for example, do not compete with the sales of another. If this is *not* true, then the additivity and thus linearity assumptions are violated [Joshi, 1980: 322].

Ralph Keeney and Howard Raiffa add "it is not always appropriate to condense an r-tuple of benefits ($b_1,...,b_r$) by means of a simple linear weighting rule" such as:

$$w_1b_1 + ... + w_ib_i + ... + w_rb_r$$

Nor is it always appropriate to use suitably chosen nonlinear transformations such as:

$$w_1g_1(b_1) + ... + w_ig_i(b_i) + ... + w_rg_r(b_r)$$

[Keeney and Raiffa, 1976: 22]

Although MOLP is an admittedly sound technique in many respects, it does not meet the requirements of this decision situation. The need for attribute linearity is unrealistic in the arena of extrinsic factors affecting force mix selection. The assemblage of attributes into linear objective functions and constraints, as described by Horn et al, poses a threat to any MOLP model's accurate representation of the subjective values offered by campaign planning experts. Perhaps Ralph Keeney says it best:

> [Because] the consequences are significant...the amount of time devoted to careful study of the appropriate values is miniscule relative to the time used to address other aspects of the decision situation. The "objective function" may be chosen in an hour with very little thought, while several person-years of effort and millions of dollars may be used to model the relationships between the alternatives and the consequences and to gather information about those relationships. Since values are the entire reason for caring about the problem, it would seem reasonable to use a portion of those resources to structure, quantify, and understand the relevant values. [Keeney, 1992: 130].

Surely, any quantification of extrinsic decision factors into a decision support tool, if optimization is a goal, should allow for accurate transformations of subjectivity as well as for an objective function. As mentioned earlier, MOLP only approaches this once

it blurs the line into becoming a MAUT technique. Says Keeney, "the objective function should be a measurable value function constructed so that the differences in value derived for the consequences have a meaning in addition to the fact that larger numbers indicate preferred consequences" [Keeney, 1992: 132].

The Analytic Hierarchy Process

Thomas L. Saaty's Analytic Hierarchy Process (AHP) is a technique that enables managers to make decisions concerning complex issues by simplifying and expediting their natural cognitive decision making processes [Saaty, 1982: 5]. Like many DA methods, AHP breaks down a complex and largely unstructured decision situation into its component parts. AHP then differentiates itself, as explained by Saaty:

> ...arranging these [component] parts, or variables, into a hierarchic order; assigning numerical values to subjective judgements on the relative importance of each variable; and synthesizing the judgements to determine which variables have the highest priority and should be acted upon to influence the outcome of the situation. [Saaty, 1982: 5].

More important to the decision situation of this research, AHP presents a highly effective structure for *group* decision making by imposing discipline upon the thought processes of the group [Saaty, 1982: 5].

AHP's two foundational constructs are pairwise comparison among multiple attributes and a hierarchic representation of attributes. It is based on three fundamental theories: 1) The human mind is quite capable of making accurate comparisons between two attributes 2) All important problems are essentially multi-criteria with an inherent hierarchical structure 3) The pairwise comparisons can be consistently combined within the hierarchical structure to yield the best alternative [Kloeber, 1992: 3].

The AHP process is carried out in four steps. First, the problem is set-up into a hierarchy with the decision objective at the top, attributes of the decision that affect its quality in the middle, and the alternatives at the bottom [Darko, 1987: 8]. The second step is the pairwise comparison of the middle decision attributes. This is a highly subjective process that involves the use of a constructed value scale that will be discussed shortly [Darko, 1987: 9; Kloeber, 1992: 8]. AHP's third step is the development of priorities, or weights, for the individual elements of the hierarchy. Again, this is rather subjective—which is desirable for this decision situation as well as many others. Finally, the fourth step aggregates these weights into a "vector of composite weights which serve as ratings of [the] decision alternatives…in achieving the most general objective of the problem" [Zahedi, 1986: 99]. Simply put, step four ranks the alternatives from best to worst [Darko, 1987: 9].

A scaling technique devised by Saaty generates consistency and flexibility in quantifying the qualitative attributes or criteria. Numerical ratios for qualitative data are made possible by Saaty's Pairwise Comparison/Importance Intensity Scale, reproduced in abbreviated form in Table 2. In AHP, even numbers are used for intermediate values.

Table 2: Saaty's Pairwise Comparison Scale

Intensity of importance	Definition
1	Equal importance of both objectives
3	Weak importance of one element over another
5	Essential or strong importance of one element over another
7	Demonstrated importance of one element over another
9	Absolute importance of one element over another

Saaty's scale is sufficiently robust from a social research standpoint [Saaty and Vargas, 1982: 24], and provides a method for combining pairwise comparisons in a hierarchical manner that allows for different scales to be used for different attributes—generating sufficient flexibility for both quantitative and qualitative comparisons [Kloeber, 1992: 8].

Two considerations in evaluating AHP for this decision problem are *consistency* and *coherence*. Coherence is addressed shortly. Consistency for a decision model means that it must capture and quantify highly subjective criteria, and is a significant consideration.

The concept of consistency is best shown by equation.

$$\begin{aligned}&\text{If } A = 2B\\ &\text{and } B = 2C\\ &\text{then } A = 4C\end{aligned}$$

As the equation shows, if A is valued or preferred twice as much as B, and B is preferred twice as much as C, then A *should be* four times as valuable as C. If A were not preferred four times as much as C, then that comparison would be considered inconsistent [Luethke, 1987: 16].

AHP provides for consistency within the model through the use of reciprocal matrices and calculating the weights with the proper eigenvector (where λ is the largest) which is approximated by the geometric mean of the ratios in the row [Kloeber, 1992: 8-9]. Saaty uses the consistency ratio:

$$m\left[\frac{(\lambda_{\max} - n)}{(n - 1)}\right] \tag{1}$$

The consistency ratio developed by equation (1) can be compared to the matrix value of *randomly generated* numerical judgements (along the scale of 1-9), and used as the indicator of consistency of the decision maker in preparing the pairwise matrix [Kloeber, 1992: 8-9]. Consistency, then, is properly addressed by AHP. However, if many criteria affect the attributes in a decision situation, or if there are many attributes themselves, then the pairwise comparisons become intractable due to the *number* (and the size of the matrix) and *not* due to the complexity of the decision [Kloeber, 1992: 17].

Coherence is yet another matter. Coherence here refers to the *rationality* of the decision support tool, best expressed by the popular *perpetual money-making machine* example.

In this example, an incoherent person claims that X is less likely than Y and that Y is in turn less likely than Z. However, he then claims that Z is *less likely* than X. Considering that he would be rewarded for the occurrence of X, he would prefer the greater chance of Y and so *pays* the rational person to substitute Y for X. The argument is of course repeated, this time with a paid substitution of Z for Y because the incoherent person thought Z more likely. Having been paid twice, the rational person then makes a third sum of money by substituting X for Z because the incoherent person thought X more likely. This leaves the incoherent person where he started, and the rational person stands to make money perpetually unless the incoherent person changes his uncertainty evaluations [Bunn, 1984: 11].

This example of an irrational approach is important because *rank reversal* of alternatives, when other alternatives are added to or subtracted from the AHP model, is a common complaint [Kloeber, 1992: 2].

Rank reversal here refers not to the ranks and weights of the criteria, rather it refers to the reversal of the rankings of the *alternatives*. In some situations in which AHP is accomplished—with the results computed and a final ranking of alternatives given—the addition or removal of a well-chosen alternative and subsequent re-implementation of the AHP process results in two or more alternatives changing relative ranking [Kloeber, 1992: 13]. Such occurs with absolutely no changes in the attributes of either alternative (i.e., changing of weights during sensitivity analysis) [Kloeber, 1992: 13]. This is circular, incoherent reasoning in which the addition of Z changes one's preference between X and Y.

How does this happen? The geometric means are dependent upon all of the pairwise comparisons. If any are deleted or added, it is very possible that the mean will change as will the weight assigned to that attribute [Kloeber, 1992: 13]. More importantly, this will occur in every criteria matrix of that model [Kloeber, 1992: 13].

Rank reversal does not make AHP invalid. The method could work in many situations and probably holds as a "descriptive model" [Kloeber, 1992: 13]. However, rank reversal in contingency planning could be detrimental. Campaign planners need *best* force mixes, and rank reversals place in serious doubt the ability of AHP to deliver. It is therefore disqualified as a candidate approach.

Multi-Attribute Utility Theory and Value Focused Thinking

MAUT has become a prominent recent contributor to decision analysis, yielding a "rigorous technique for combining attributes multiplicatively (thereby incorporating nonlinearity), and for handling uncertainty in the attribute values" [Horn et al, 1994: 1].

Value Focused Thinking (VFT) is a modification of MAUT [Klimack, 2000] developed by Ralph Keeney that differs in two primary ways: its treatment of nonlinearity of model inputs (discussed later), and its focus on a problem's *values* (objectives) rather than its candidate *alternatives*.

Stanley Stafira claims that DA has but two main modeling techniques: alternative-focused thinking and value-focused thinking [Stafira, 1995: 2-3 to 2-4]. Perhaps a better way to state this is that the *chosen methodologies* of any DA technique can be either alternatives driven or values (objectives) driven [Parnell et al, 1998: 1338]. The objectives driven approach starts with fundamental objectives and underlying sub-objectives and develops quantifiable attributes for the lowest level objectives up through the model, while the alternatives driven approach finds the alternatives first and seeks identifiable attributes to then differentiate these alternatives [Parnell et al, 1998: 1336]. Of the two approaches, the objectives driven approach is more appropriate for strategic situations [Parnell et al, 1998: 1336]. Table 3 illustrates the differences in the problem solving steps between the two approaches [Parnell et al, 1997: 7].

A constructed value *hierarchy* is the cornerstone of the VFT technique [Buzo, 2000: 21]. Value hierarchies serve as graphical representations of all of the relevant issues needed in order to determine an overall relative value for each candidate

Table 3: Alternatives-driven vs. values-driven models

Step	Alternative-Focused Thinking	Value-Focused Thinking
1	Recognize decision problem	Recognize decision problem
2	*Identify* alternatives	**Specify values**
3	**Specify values**	*Create* alternatives
4	Evaluate alternatives	Evaluate alternatives
5	Select an alternative	Select an alternative

alternative [Buzo, 2000: 21]. A hierarchy provides for information collection, identification of alternatives, facilitation of communication, and the evaluation of alternatives [Kirkwood, 1997: 19-23].

A value hierarchy can be constructed from the bottom up by identifying individual organizational tasks or sub-objectives, grouping them together with the use of affinity diagrams, and then structuring the hierarchy into appropriate tiers [Parnell et al, 1998: 1340].

Value hierarchies constructed from the top down are referred to as the "gold standard" [Parnell et al, 1998: 1338]. Top down constructions are based upon an organization's mission, vision, or strategy, with the objectives and tasks broken into progressively lower tiers until the situation is wholly encompassed. These constructions necessarily involve the expertise of an organization's top decision makers and/or ample organizational guidance as to the factors.

Whichever method is used to build the hierarchy, Kirkwood emphasizes the "test of importance" for any factor whose value consideration is to be included. The test is that a factor should be included *only* if potential variations among the candidate alternatives—with respect to the factor under consideration—could change the preferred alternative [Keeney, 1997: 19].

Once a hierarchy is constructed to model the decision situation, an evaluation measure is assigned to each objective to measure its degree of attainment, such as "*higher salary* (the evaluation measure) for a job seeker" [Kirkwood, 1997: 12]. Evaluation measures serve to quantify the decision maker's subjective values. VFT requires the *normalizing* of respective evaluation measures whereby the analyst does *not use* (as the measure of performance) the actual evaluation measure *score*, but rather the "*proportion of the way along the allowed range* of that evaluation measure scale where the score for the alternative lies" [Kirkwood, 1997: 57]. The evaluation measure, then, converts a factor's scored quantity from its respective units into a common set of units, allowing many criteria to be combined into a single measure.

VFT incorporates nonlinearity through the functions of its evaluation measures, rather than through a model-wide multiplicative process. Each evaluation measure, upon elicitation of values from the expert decision maker, becomes a single-dimension value function. These single-dimension values are typically exponential, piecewise linear, or discrete functions [Clemen, 1996: 80; Kirkwood, 1997: 62-68].

VFT single-dimension value functions convert the raw graphical representations of candidate alternatives to *values* via inverse transformation upon the value graphs of the objectives (i.e., an exponential curve). Whichever scale is used for the values (0 to 1, 0 to

10, or 0 to 100) must be used consistently for all values within the model [Kirkwood, 1997: 61].

VFT models incorporate relative weights for the single dimension value functions. The weighting method is arguably more precise than that of the Kepner-Tregoe method or AHP. A number of weighting methods can be applied [Kirkwood, 1997: 68-70; Clemen, 1996: 546-552], of which the "swing weight" method advocated by both Kirkwood and Clemen is discussed.

The swing weight method first has the decision maker rank-order all of the measures and then study the ranges of each of the measures separately. After identifying the ranges of swings for the measures, the decision maker then begins pairwise comparisons between measures. This involves the decision maker determining how much swing measure A must have in order to match the value of B when B is swung from its lowest to its highest value [Kirkwood, 1997: 71-72; Clemen, 1996: 547]. Equation (2) shows that A need swing only 75 percent of its range to equal the swing of B through its full range.

$$0.75\text{A} = \text{B} \tag{2}$$

The process of pairwise comparisons continues until there is one less equation than the number of objectives [Buzo, 2000: 26]. Once all of the comparisons are complete, the weights are normalized to sum to 1. The analyst now has a nearly complete VFT model lacking just one component—the multi-objective value function. The most common multi-objective value function used with VFT is the additive form:

$$v(x_n) = \sum_{i=1}^{n} w_i * v_i * (x_i)$$

Where x is the overall value objective, x_i is the raw score of attribute i, v_i is the single-dimension value function, w_i is the weight of importance on attribute i, and n is the total number of evaluation measures.

The appropriateness of additivity in a VFT model is thoroughly addressed by Clemen, Keeney, and Kirkwood [Clemen, 1996: 579-580; Keeney, 1992: 132-138; Kirkwood, 1997: 238-239]. The requirement for an additive value function is for mutual preferential independence among attributes. One should note that careful, proper selection and arrangement of objectives within a value hierarchy can almost assure mutual preferential independence. However, formal testing should be accomplished. The reader is encouraged to reference Kirkwood's Theorems 9.19 and 9.20 in addition to Theorem 3.7 of Keeney and Raiffa [Kirkwood, 1997: 238-239; Keeney and Raiffa, 1976]. Clemen also offers formal testing procedures [Clemen, 1996: 580-582].

VFT is certainly a viable candidate DA method for this highly subjective decision situation. It has the potential of accurately converting multiple subjective judgements into quantifiable value measures and combining them in a manner that accounts for the nonlinearity of responses. More importantly, it does so with a focus on the values or objectives of the decision maker as the driving force. This is important because an alternatives-focused method would limit potential solutions to a pre-determined and possibly finite set of choices. VFT leaves the decision maker free to create or select any alternative that meets the requirements generated by his or her value model.

The Preferred Method for this Decision Problem

Following a background review of DA theories and methodologies, and a comparison of five qualifying candidate approaches, VFT was selected as the method for modeling this decision situation. The efforts of this research validate Buzo's selection of VFT for the original modeling of this subject [Buzo, 2000].

In his model, Buzo incorporated *go/no go* constraints for a number of the extrinsic decision factors, such as "*Host Nation: Allow Assets In?*" [Buzo, 2000: 25]. This is common for many VFT models [Keeney, 1992; Kirkwood, 1997]. However, for inclusion of such constraints into an additive hierarchy, some modification within the model's functions is necessary, most commonly the *IF* statements provided by most spreadsheet applications.

This research considers the possibility of creating a filter model for the VFT approach used; the discussion of this application is reserved for Chapter IV. A filter serves the *Go/No Go* and *Go/No Go with Optimization* rules identified by Allan Easton [Easton, 1980: 183-189]. The *Go/No Go Rule* provides for a pre-testing of alternatives that can only result in one of the following conclusions: 1) one alternative will survive the test, 2) no alternative will survive, 3) two or more may survive [Easton, 1980: 183]. This rule provides for pre-selection of only those alternatives that need to be subjected to further evaluation by other means [Easton, 1980: 185].

Easton also provides for *single attribute* optimization following a comprehensive go/no go test that incorporates *all* of the other attributes—*the Go/No Go with Optimization* [Easton, 1980: 187]. This researcher posits that a filter using this rule could still be appropriate in the case of VFT because the VFT model's multi-objective value

function could serve as the single attribute following the go/no go phase of other attributes. Regardless, Kepner-Tregoe and other DA techniques (including heuristic, cognitive approaches) allow and encourage the use of go/no go filters. The methodology of the research, discussed at length in Chapter IV, outlines the process for considering use of a go/no go filter with VFT.

IV. Methodology

Overview of the Research: The Questions and Phases

This research was comprised of an extensive literature review and multiple interviews (in person and via email) with subject matter experts in an effort to elicit and extract information to create a decision support tool for force mix selection during crisis action planning.

The research was designed to answer the six primary research questions listed in Table 4, where they are linked to their respective research phases. This research addressed the questions out of turn because research question 5 pertained *initially* to the selection of the interview participants, and research question 3 was best addressed—via the modified Delphi study—only after the selection of the most appropriate DA method.

The four research phases were: I) CDM interviews and content analysis, II) literature review to determine the best DA technique, III) modified Delphi interviews, and IV) development of the final decision support tool. Table 4 shows the phases and their corresponding research questions.

Table 4: The four phases of research

PHASE I	CDM / CONTENT ANALYSIS	QUESTIONS 1, 2, 5
PHASE II	LITERATURE REVIEW	QUESTION 4
PHASE III	ITERATIVE INTERVIEWS (DELPHI)	QUESTIONS 3, 4, 5, 6
PHASE IV	DEVELOPMENT OF MODEL	QUESTIONS 3, 4, 5, 6

Phase I: CDM Interviews and Content Analysis

The first phase addressed research questions 1, 2, and 5. The first research question was: *Can the factors affecting force mix selection in response to theater crises be clearly categorized as* extrinsic *and* intrinsic, *and can these categories be clearly defined?* The second question was: *What extrinsic factors are important to campaign planners when selecting aircraft force mixes in response to theater crises?* And the fifth research question was: *Can the research results be applied USAF-wide?*

In addressing the research questions, four objectives were established for Phase I. The first objective was to clearly *distinguish,* if possible, what constitutes extrinsic and intrinsic force mix selection decision factors in the eyes of the subject matter experts—which would lead to definitions for each type. The second objective was to identify *all* of the extrinsic factors so that they could be evaluated as contributors to the decision support tool. The factors, to lend value to this research, would necessarily have to be mutually exclusive and collectively exhaustive (MECE). Establishing factors to meet these criteria was the third objective. The fourth and final objective of this phase was to develop and refine an accurate *definition* for every factor identified. Achievement of these four objectives assured the generation of sound answers to questions 1 and 2.

Content analysis of the appropriate literature was the first step. The intent during this early literature review was to include every factor identified and then to add any other factors identified later via interviews. Thus, a factor would be included if either extracted from content analysis or elicited via interview, or both—with the exception of those factors identified in Buzo's thesis, which were to be validated [Buzo, 2000]. This provided the best avenue to meeting the objective that *all* extrinsic factors be identified.

The appropriate literature from which to glean decision factors on this subject was the official guidance that is provided to campaign planners throughout the USAF—the DoD and USAF instruction manuals on joint planning previously discussed. Buzo's thesis, being a compilation of extrinsic decision factors into a single decision support tool, contained 25 such factors. However, because this research sought to independently investigate the validity of those factors, they were not included in the results of the content analysis.

In order to distinguish between extrinsic and intrinsic factors, examples of both were extracted. This was done to explain the differences between the two types in the minds of the subject matter experts who were to be interviewed later. This in turn helped to define the two types of factors. The factors extracted via content analysis are shown in Figure 1.

Once the collection of extrinsic and intrinsic decision factors were in hand, interviews with the experts, using the Critical Decision Method (CDM), could begin. CDM is an interviewing approach, discussed at length in Chapter II, that puts the focus on those *most critical* cognitive points or tasks of a job. With CDM, "issues can be described as points in the campaign planning process where critical decisions, decisions that a novice would have sufficient difficulty overcoming, may be required" [Buzo, 2000: 45]. It is these critical issues that could hinder timely selection of the best force mix.

Selection of the participating experts was crucial to properly addressing research question 5, *Can the research results be applied USAF-wide?* Later efforts would answer this question fully but this was the necessary first step.

Included as interview subjects were 34 campaign planning experts from the Air Staff (HQ USAF), Air Combat Command (ACC), Air Force Southern Command (SouthAF), Air Force Special Operations Command (AFSOC), Air Force Central Command (CentAF), Joint Forces Command (JFCom), USAF Fighter Weapons School, RED FLAG, USAF Air Expeditionary Forces Center (AEFC), USAF College of Aerospace Doctrine (CADRE), and the AFSOC Command and Control schoolhouse (C2TIG). Even the USAF Reserves were included, as representatives within the AEFC. This highly diversified subject pool was required to provide a broad range of perspectives necessary for validity. Scarcity of resources precluded interviews with expert representatives from overseas commands. However, such interviews were unnecessary because those commands predominantly *employ* forces during conflict rather than selecting which force mixes to *deploy.*

Aside from the necessary representation of all appropriate organizations, this research required a wide diversity of expertise relating to operations. The subject pool had 26 members with in-the-cockpit operational experience with a wide array of military aircraft including: F-15, F-16, F-4, F-111, A-10, C-130, KC-10, KC-135, and B-52. Of the 34, eight were career logisticians. Finally, the subjects had to pass the following base requirements: minimum grade of O-4 (or civilian equivalent), minimum of 12 years USAF operational experience, minimum of two years of campaign planning experience. All subject matter experts met these requirements.

The materials used for the CDM interviews were borrowed in large part from Buzo's appendices [Buzo, 2000: 100-112]. His "bullet background paper" was modified to meet the objectives of this research and sent via email to all participants prior to the

interviews. The paper, presented in Appendix A, provided sufficient background to prepare each expert for the task at hand.

The CDM process is largely unstructured to allow experts to relay completely their own personal experiences. However, the four objectives identified earlier necessitated a semi-structured approach to ensure elicitation of only appropriate material. Buzo's original interview script [Buzo, 2000: 102-104] provided the necessary structure. Again, this was modified (extensively) to meet the objectives specific to *this* research. The modified script, seen in Appendix B, added questions pertaining to the distinction between extrinsic and intrinsic factors, the assurance of MECE among factors, and the potential definitions for extrinsic, intrinsic, and each of the individual factors. A key difference between this script and Buzo's is that this script aimed to elicit all of the campaign planning factors rather than just the extrinsic.

The materials used also included Buzo's list of extrinsic factor definitions [Buzo, 2000: 105-112] and a listing of factors extracted via content analysis.

The procedure for conducting a CDM interview is to use verbal "probes" (questions) to elicit critical decision points from the subject [Klein et al, 1997: 2; Militello, 1998: 1622]. The probes for this research were the questions (and interviewer reminders) printed on the script.

This research modified the CDM procedure used by Buzo in two ways. First, each participant was asked to apply *any scenario with which he or she felt most familiar*. This ensured the greatest possible diversity, significantly enhancing the applicability of this research USAF-wide. In Buzo's research, participants were limited to a Southwest Asia Theater scenario [Buzo, 2000: 51]. The second modification was to introduce each

participant to all of the extrinsic factors that had been extracted via content analysis—but only once each participant had exhausted his or her personal list of factors.

Definitions were elicited for each factor identified by each participant. Following this, definitions for the newly-introduced factors provided by the researcher—and agreed upon by the participant—were elicited. Finally, the participants compared Buzo's factors and definitions to those that had been elicited, with appropriate adjustments made.

Phase I of the research met all of its objectives, properly addressing research questions 1 and 2, and providing the foundation for answering research question 5. Pages 15-19 of Chapter II discuss the distinction between extrinsic and intrinsic decision factors, with definitions for both categories presented on page 16. The final set of mutually exclusive, collectively exhaustive extrinsic decision factors is shown in Appendix C, and is very similar to Buzo's with the exception of the factor definitions. The updated definitions are presented in Appendix D. Further discussion of the results of Phase I is reserved for Chapter V.

Phase II: Literature Review to Determine the Best DA Method

The objective of this phase was to determine the most appropriate DA method for modeling the decision situation and creating a requisite decision support tool. Accomplishment of this single objective would answer research question 4, *How should these factors and the relationships between them be modeled?*

To determine the most appropriate DA technique, it was necessary to first investigate the background and progression of DA in order to provide for the selection of a method based on a foundation of knowledge rather than just simple preference or

convenience. Once the comprehensive background was established, separation and categorization of methods into families of techniques and schools of thought could be accomplished.

After categorizing the general groups of DA techniques, an analysis of the requirements for this decision situation was required in order to determine which technique(s) would be most appropriate. This decision situation involves multiple attributes, severe time constraints, critical consequences, non-sequentiality, and highly subjective attribute comparisons. Discussion of this was presented in Chapter III.

The characteristics of this decision situation dictated a class of DA techniques capable of measuring multiple attributes and quantifying otherwise subjective criteria, among other considerations. This realization narrowed the search to the multi-criteria decision making (MCDM) class of models under the Operations Research umbrella.

After comparing the characteristics of this smaller set of candidate techniques to the requirements of the decision situation, Value Focused Thinking (VFT) was selected as the most appropriate model. This in effect validated the work of Buzo in establishing his decision support tool [Buzo, 2000].

VFT requires the assembling of criteria into a value hierarchy. Therefore, Buzo's original value hierarchy was reproduced exactly, for use in Phase III of the research [Buzo, 2000: 80]. In addition, another candidate hierarchy was constructed and used alongside Buzo's in the next phase. This hierarchy resembled Buzo's, but with a *go/no go* component advocated by Easton, Kepner, and Tregoe [Easton, 1980; Kepner and Tregoe, 1965]. This second hierarchy is shown in Figure 11.

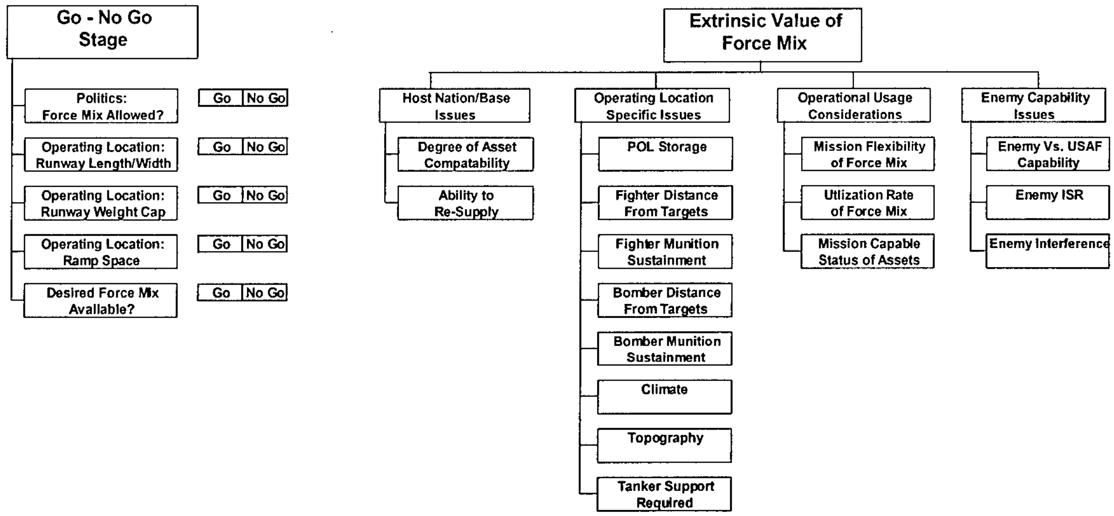


Figure 11: Candidate VFT hierarchy

Phase III: Iterative Interviews (Modified Delphi) to Attain Consensus

Phase III was structured to answer research question 3, *How are these factors quantified and what are the relationships between them?* In addition, it laid the groundwork for addressing research question 6, *How can the now-quantified extrinsic factors be effectively combined with the intrinsic factors to develop an overall asset set utility or value?*

Four objectives were established for this phase. The primary objective was to elicit single-dimension value functions for each of the extrinsic factors, in accordance with VFT methodology. The second objective was to elicit initial relative rankings of importance among the factors in order to *seed* the final two rounds of modified Delphi, which would provide the weights for the factors. Evaluation of the two candidate value hierarchies was the third objective. And the fourth objective, perhaps most important to

force mix selection, was to begin development of a preliminary theory for the relationship between extrinsic value and intrinsic value—in the eyes of the experts—so that a mathematical representation of such could be developed.

Phase III was comprised of an iterative interviewing and email questionnaire process referred to here as a modified Delphi study. The methodology included a comprehensive first round of face-to-face interviews that focused on all four Phase III objectives. The process exhibited Delphi characteristics in that all participants were guaranteed anonymity, the process involved more than one round, and the results were summarized and resubmitted to participants between rounds. It cannot be called a proper Delphi because one could argue an insufficient number of rounds and because the specific summarization techniques advocated by Dalkey and others were not incorporated [Dalkey, 1968]. The second and third rounds of the modified Delphi were in the form of email questionnaires to elicit final weights for the factors.

The participant selection process of Phase III differed from that of Phase I. For the iterative interviews, only campaign planning experts from CADRE, ACC, AEFC, and SouthAF were included. ACC and AEFC are the primary brokers of asset sets in support of contingency operations from the continental United States [Brown, 2000; Broardt, 2000], and CADRE personnel are the teachers and developers of basic aerospace doctrine for the 21st century. Additionally, because Buzo's factors and model had thus far been validated, his CentAF-elicited single-dimension value functions and factor weights were accepted as valid, leaving SouthAF as the potentially opposing opinion to CentAF. With proper sensitivity analysis (discussed later), one could be confident that value functions

and weights elicited from these four agencies, along with CentAF, would generate a decision support tool with USAF-wide applicability.

The inventory of materials used for Phase III begins with the list of extrinsic factors constructed during Phase I along with Buzo's original list of extrinsic factors [Buzo, 2000]. Buzo's *list* had been validated, but his *hierarchy* stood unchallenged. Therefore, the shorter list compiled during Phase I—which had some of the factors combined and set aside as a *go/no go* filter within the candidate hierarchy—was also evaluated by the experts during the iterative interviews. The list of factor definitions (Appendix D) was an integral part of the interview materials. Additionally, both hierarchies were included for evaluation.

The materials for Phase III also included the email questionnaires used to determine the relative weights, discussed later, and complete sets of blank single-dimension value function elicitation graphs, discussed here.

Each extrinsic factor has its own single-dimension value function within a VFT model, therefore each extrinsic factor was represented by a *blank* value function elicitation graph. Figure 12 shows such an example graph with a linear value function, as might be elicited from a decision maker. Notice that the X-axis is reserved for the range of real values that a particular factor can produce. The Y-axis reflects the *decision maker's transformed value* given that a factor's real score lies at some point along the X-axis. This Y-axis value's range is from 0 to 1, providing for the normalization of all such values into like units of measurement and enhancing the objective value function's overall rating of a candidate alternative.

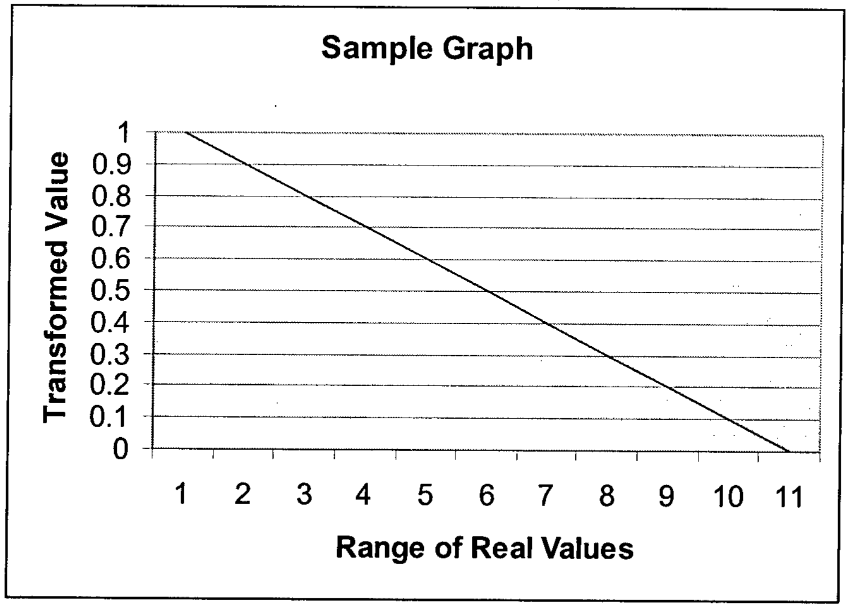


Figure 12: Sample single-dimension value function graph

The procedure was identical in each iterative interview. Each interview began with participants subjectively evaluating the two candidate value hierarchies. These evaluations were unstructured and exploratory, whereby participants were free to sketch proposals and discuss at length any concerns or ideas. Integral to the development of value hierarchies is the determination of *parent issues* and *sub-issues*. Note that parent issues are not decision factors, but rather *categories* of decision factors. The sub-issues within a parent issue constitute the factors. As discussed later, VFT calls for factors to be weighted so that the weights are additive to 1 *within* each parent issue. The parent issue weights are then additive to 1. The weighting process is discussed at the end of the Phase III section.

Next came participant evaluation of the definitions and proposed ranges of real values for each of the extrinsic factors. Elicitation of the X-axis *ranges* from experts, such as 0-100 percent for mission capability of assets or 0-3000 miles for the range of

fighter aircraft (refueled), was vitally important to the process. Only with realistic value ranges, having the correct upper and lower bounds, could realistic value transformations occur.

Once the factor definitions and ranges—along with one or both of the hierarchies—were deemed correct, the painstaking process of single-dimension value function elicitation could begin.

Each extrinsic factor's blank elicitation graph was presented to the experts one at a time. Each expert was asked to identify as closely as possible the point along the X-axis (the factor's real range) that his or her transformed value began to drop from its high of 1. The expert was then asked to identify at which point the transformed value began to increase from its low of 0. Both points were marked in pencil directly on the particular graph. These values did not necessarily coincide with the extreme points of the factor's pre-determined real range.

Once the extreme points of zero value and full value were identified, the expert was asked to identify the transformed (Y-axis) value that the values within the real range represented for him or her. This was accomplished via the drawing or sketching of a line or curve from one extreme to the other. This *line* could take any form the decision maker deemed appropriate. The process was repeated for every extrinsic factor with the exception of all *go/no go* constraints, for which transformed values are necessarily 1 or 0.

Once all of the graphical representations of value had been elicited from all of the participating experts, that portion of the interview sessions was complete. Mathematical transformation of each curve or line into a single-dimension value function was held for later, upon completion of all interviews. This was done using Microsoft Excel

spreadsheet applications to create linear, piecewise linear, and exponential functions that would be used to convert candidate force mix scores to values between 1 and 0 for each factor.

Upon completion of the last graphical factor value representation, each participant was asked to provide a rank ordering for all 26 extrinsic factors. These rank ordering sheets, an example of which can be found in Appendix E, provided a grouping according to relative importance that enhanced the development of the factor weighting questionnaires used in the final rounds of modified Delphi, the last step of Phase III.

However, the in-person interviews did not end with elicitation of the relative rankings. At the end of each interview, every participant was asked his or her opinion on the relationship between extrinsic and intrinsic factors; such as which, if any, should be weighted more than the other. Particularly, participants were asked, "If the *extrinsic* value of candidate mix A were .7 and the *intrinsic* value were .3, how would that rate against mix B, of which the sum is equal but the values are reversed?" These discussions were almost completely unstructured and sometimes lengthy. This was desirable because the intent was to develop a theory of the relationship that could be accurately modeled mathematically and would subsequently answer research question 6.

The final step of Phase III was the final round of modified Delphi study—administering of the questionnaires that developed the relative weights for the factors. Each participant in this phase was first emailed an instructional talking paper on the characteristics of performing swing weight analyses. This was done three days prior to the emailing of the actual questionnaires to ensure that each participant thoroughly

understood the process. The talking paper was a modified version of that used by Buzo [Buzo, 2000: 174-176], and can be viewed in Appendix F.

Having given the participants three days to digest the process, the modified Delphi round two questionnaires were emailed. The rank ordering of factors accomplished earlier during the in-person interviews provided for the structure of the questionnaire, allowing for the order by which sub-issues (the factors) would be weighted against each other. Hence, the highest-ranking sub-issue *within each* parent issue could be compared to every other sub-issue within the same parent issue.

Within the questionnaire, all of the necessary comparisons were put in table form. A narrative explained the process and provided yet another swing weight example to ensure participant understanding. The questionnaire elicited only one task, worded as follows: *For each of the factors or parent issues presented, "state how many times more important the swing from best score to worst score for the issue in Column A is than the swing from best score to worst score for the issue in Column B"* [Buzo, 2000: 59]. This wording from Buzo's work was left completely as is, to ensure reasonable duplication of his weighting elicitation process. The questionnaire also asked for any comments the participant might want to provide as justification for his or her weightings.

Swing weight analysis calls for the comparison between two factors' loss of value along their entire ranges, from highest possible scores to lowest possible scores. The decision maker then need only determine which loss of value is more important to him or her and by how much (or how many times). Analyzing the swing in value, the decision maker might determine that A's complete loss in value is twice as important as B's. Therefore, A would have twice the weight of B, or by equation, $A = 2B$.

Within its response table, the questionnaire also provided for such comparisons between parent issues, the ordering of which was also determined by the earlier in-person rank ordering of all factors. Those factors that had been ranked higher by the round 1 participants *implied* that their parent issues were of greater importance. Of course, this was not accepted as fact but stood only for the development of the questionnaire in order to provide for the comparisons. The questionnaire used for the study is exhibited in Appendix G.

Once all of the questionnaires were completed and returned, each factor's highest and lowest weights, along with their respective *average* weights, were tabulated. The same was done for parent issues. The summarized results, along with the anonymous comments of the participants, were attached to a second questionnaire and emailed to the participants. The omission of swing weight process instructions notwithstanding, this second questionnaire was a duplicate of the first. Participants were asked to evaluate the intermediate results and anonymous comments, re-evaluate their own judgements, and return their updated questionnaires. The results of this third and final round of modified Delphi were then averaged for every factor and parent issue, and these were normalized to sum to 1 *within* parent issues and again *among* parent issues.

Phase IV: Development of the Decision Support Tool

Phases I-III of research provided a step-by-step approach to: First, gathering the necessary subjective information; then, choosing the most appropriate DA methodology for modeling and constructing the decision support tool; and finally, converting

subjective inputs into quantitative values and relative weights with which to formulate an objective value function for scoring any candidate force mix.

The two objectives for Phase IV were to develop the final decision support tool and to develop a mathematical formula to represent the relationship between this tool and the intrinsic value of a force mix.

To develop the VFT decision support tool, all of the individual graphical representations of value for each of the factors had to be converted into single-dimension value functions. Additionally, the factor weights had to be converted into *global* weights to represent each factor's importance within the overall model. More on global weights is presented later.

To convert raw graphical representations into single-dimension value functions, Kirkwood provides piecewise linear and exponential function formulations (written in Visual Basic) for Microsoft Excel spreadsheets [Kirkwood, 1997; 62-68] of which both Buzo and this researcher made extensive use [Buzo, 2000: 24]. These formulas provide for relatively simple inverse transformation of a decision maker's line or curve into a corresponding value between 0 and 1. Creating single-dimension value functions, however, is just the beginning.

Each value function must have the appropriate level of importance, or weight, within the model. This then becomes its *global* weight. Phase III's modified Delphi process provided the foundation for this with its comparisons between factors.
To begin, all of the weights for the sub-factors within a parent issue must sum to 1. For example, if X and Y are the only two factors within parent issue P, and $X = 2Y$, then the weight for X is .67 and the weight for Y is .33 (rounded here). But these are only relative

weights within the parent issue. To become global weights that reflect each factor's importance to the model, each of the factor weights must be multiplied by the weight of the parent issue (which is relative to the other parent issues and of which all must also sum to 1). If the weight of P is .4, then the global weights for X and Y are .27 and .13 (rounded), respectfully. Global weights were calculated for all of the factors.

Because the goal of this research is to create a decision support tool with USAF-wide applicability, single-dimension value functions had been elicited from multiple groups of experts. Buzo had elicited just one value function for each factor [Buzo, 2000]. This research elicited *four* separate and distinct functions for each. Although simple averaging of these functions is advocated by some [Miller, 1970; Joshi, 1980], specific guidance on how to do so was not provided, and such should not be done in this case without justification. Given that averaging of value functions could be accomplished, sensitivity analysis on each factor's impact on the rankings of candidate force mixes would either provide justification for averaging the value functions or necessitate a feedback loop with the experts to modify those functions. However, before sensitivity analysis could be accomplished, a set of candidate force mixes had to be found.

A straw model of candidate force mixes was developed based on a notional level of capability to be met, matched to notional suitability ratings for individual aircraft. Five aircraft types, three fighters and two bombers, were included in the model. They were each given notional suitability ratings for each of three mock aerospace missions (AA, AG, PB). These aircraft types were then combined into 51 distinct force mixes—all sufficient to attain a basic capability of 10 "AA", 20 "AG", and 2 "PB" aerospace missions, respectively. This model provides for multiple force mix combinations that

each present an *intrinsic value* to accomplish specified aerospace missions. These combinations can then be evaluated within the VFT *extrinsic* factor decision support tool to generate an overall extrinsic value. With such a straw model, sensitivity analyses of the individual single-dimension value functions could progress.

For the sensitivity analysis, the value functions that Buzo had elicited from CentAF were considered valid groundwork to be included in the averaging of the newly attained value functions of this research. Therefore, each factor had *five* single-dimension value functions. These value functions were averaged for each factor, and the model assembled using these aggregated values. Using the developed straw model, candidate force mixes were entered. This produced scores that resulted in a rank ordering of force mixes from most desirable to least desirable.

Using this rank order of candidate force mixes as the baseline, the single-dimension value function of *one factor at a time* was altered to represent a single agency's value function (for example, AEFC's value function for Resupply)—and the model was run again. In each case, the single agency value function that was most dissimilar to the USAF-wide function was selected. This produced subsequent sets of rank-ordered candidate force mixes. The process was repeated for all of the 16 extrinsic decision factors.

If an agency's single-dimension value function produced a *different rank order* among any of the top three alternatives—with all of the remaining *averaged* value functions remaining constant—then that elicited value function failed the sensitivity analysis and feedback with the originating expert was in order. If the agency's value function for a single factor did not change the rank order, then that factor's *averaged*

function was deemed an appropriate representation of the expert group's judgement. A second decision rule was that, if a participating expert was unwilling to alter his or her value function in light of having failed the sensitivity analysis, then all of his or her value functions would be removed from the model, with appropriate documentation of the anonymous dissenting opinion. The underlying reasons for the dissenting perspective would then be investigated.

Sensitivity analyses was also necessary for the parent weights within the decision support tool. This was accomplished by altering one parent weight at a time, but only as far as its minimum and maximum weights as had been elicited by the experts. When a weight was altered, the tool was run with the resultant rank ordering of candidate force mixes observed. This provided valuable insights as to both the factors and the weights of those factors within the model. Sensitivity analyses of the value functions and parent weights constituted tests *internal* to the model.

Testing the *external* sensitivity of the model required investigation as to its affect on an *intrinsically* scored and ranked set of force mixes (using notional suitability scores attained via the straw model). Discussion of this sensitivity analysis is reserved for Chapter V.

This fourth phase of research also involved an effort to generate a formula that accurately represents the relationship between the extrinsic value and intrinsic value of force mixes. *Overall* force mix value would be a combination of both. While research into the intrinsic value of force mixes is beyond the scope of this effort, it stands to reason that a quantified intrinsic value, once known, can be mated with a quantified extrinsic value. The challenge was to develop a working theory of the possible group

preference of one over the other as discussed earlier. If no preference exists, simply summing or multiplying the two values could produce a sound result. However, if global preference of one over the other existed, however slight, it must be reflected in the mathematical relationship in order to ensure maximum representation of the subject matter expert's group judgement. Feedback from the expert participants showed just such global preference for intrinsic over extrinsic.

Phase IV concluded with an investigation of how to mathematically reflect a *slight preference* for intrinsic value over extrinsic value. This centered around the insightful concept that intrinsic value is a combination of *capability* and *suitability*, and that only one of the two required preferential status in force mix scoring.

Summary

This chapter presented a step-by-step explanation of the four phases of research used to develop an extrinsically-oriented decision support tool to aid campaign planners in selecting the most appropriate force mixes during crisis action planning. Numerous objectives were established to properly address the six research questions. All of these objectives were met.

The Phase I section discussed the separation of extrinsic and intrinsic factors and elicitation of the definitions for each category; elicitation and extraction of the relevant decision factors; subjective expert evaluation of the independence and mutual exclusivity of each; and definitions for each.

The Phase II section discussed the conduct of the literature review to determine the most appropriate DA technique for this research situation.

The three-round modified Delphi study was addressed in the Phase III section, with the focus on eliciting quantified single-dimension value functions and determining relative weights of factors within the model. Also discussed were the subjective expert evaluations of candidate hierarchies and the preliminary formulation of a theory pertaining to the relationship between extrinsic value and intrinsic value.

Finally, the Phase IV section outlined the decision tool development including comprehensive sensitivity analyses on both value functions and global weights. It also addressed the trial and error mathematical investigation to reflect slight preference for intrinsic force mix value over extrinsic value.

The next chapter presents the results of the overall research effort.

V. Results

Phase I: The CDM Interviews and Content Analysis

CDM interviews and content analysis addressed research questions 1 and 2, while the selection of the participating subject matter experts provided the first step for addressing question 5.

All of the 34 study participants agreed on the existence of both extrinsic and intrinsic campaign planning decision factors, and on the clear separation between the two types. This unanimous agreement was important to the basic premise of this research—that a decision support model could focus solely on extrinsic factors not pertaining to the mission-specific or absolute capabilities of candidate force mixes.

Many potential definitions surfaced for what constitutes an extrinsic factor, and most could prove suitable. Definition 2 incorporates the relevant inputs from the subject matter experts: Extrinsic decision factors are situational considerations, external to and independent of a weapons platform's design, that affect determination of the appropriateness and subsequent goodness of that weapons platform for a specified mission—given a specific contextual environment that requires evaluation.

Likewise, there were many definitions presented for what constitutes an intrinsic decision factor, and the relevant inputs have been incorporated. Definition 1 is: Intrinsic factors represent a weapons platform's fundamental ability to accomplish a specified aerospace mission or tasking, and are limited to determinations of efficacy in a given situation related only to the designated purpose of its design.

In addition to defining extrinsic and intrinsic factor types, this phase elicited an exhaustive list of 22 mutually independent, specific extrinsic factors. The final factors included in the decision support model can be viewed in Appendix C, with their associated descriptions in Appendix D. These are the extrinsic decision factors important to campaign planners in selecting force mixes in response to theater crises. The claim of an *exhaustive* list is based on the 34 interviews with experts and the content analysis of USAF and Joint guidance, all of which combined to produce just these factors. Tests for independence were comprised of conceptual implementations of Kirkwood's Theorems 9.19 and 9.20 in discussions with subject matter experts, sans the graphical and formula representations [Kirkwood, 1997: 238-239].

Can the factors affecting force mix selection in response to theater crises be clearly categorized as extrinsic and intrinsic, and can these categories be clearly defined? This was the first research question, and it has been satisfactorily answered. All of the subject matter experts agreed on the separation, and all of the experts helped to enhance the development of Definitions 1 and 2.

The second research question has also been answered. What extrinsic factors are important to campaign planners when selecting aircraft force mixes in response to theater crises? The 22 factors identified by Phase II of this research, and presented in Appendices C and D, are those that are important to campaign planners.

Phase II: Literature Review to Determine the Best DA Method

The purpose of the second phase of research was to address research question 4, which involved selection of the most appropriate Decision Analysis (DA) technique to

model the decision situation at hand. A search of DA literature provided the foundational information necessary to properly compare DA methodologies. With background on various techniques and advancements, along with an understanding of the decision situation at hand, comparisons could be made on the basis of knowledge and applicability rather than on the basis of convenience or the specific competencies of the researcher.

In order to ascertain the most appropriate DA technique, research question 4 asked: How should these factors and the relationships between them be modeled? This question has been satisfied with the selection of Multi-Attribute Utility Theory using Value Focused Thinking (VFT). The selection criteria can be reviewed in Chapter III.

Selection of VFT as the method of choice necessitated development of a value hierarchy with which to model the relationship among extrinsic decision factors. Such a hierarchy was developed. This intermediate hierarchy was introduced to experts during Phase III of the study (see Figure 11), along with the hierarchy developed by Buzo [Buzo, 2000: 67]. The final hierarchy is based on the feedback provided by the subject matter experts and is presented in the Phase III section of this chapter.

Phase III: Iterative Interviews (Modified Delphi) to Attain Consensus

While this phase of research addressed all of the six research questions, its purpose was to lay the groundwork in answering question 3—*quantifying* the extrinsic decision factors.

The in-person, first round of modified Delphi study established the single-dimension value functions (SDVF's) for each of the 16 *scored* extrinsic decision factors (six of the factors are *go/no go* constraints that are not given SDVF's). Individual sets of

SDVF's were elicited from AEFC, CADRE, SouthAF, and ACC, for a total of 64 SDVF's.

Each SDVF was transformed from its hand-drawn representation into a Microsoft Excel-based value curve using "ValueE" and "ValuePL" functions [Kirkwood, 1997: 81]. Coding of these functions was through Microsoft's Visual Basic programming and can be viewed in Appendix M. Initial quantification of the extrinsic factors was complete. This involved quantification relative to *each agency independently*. The final quantification of factors, combining all into USAF-Wide representations, was reserved for the final phase of research.

Phase III also allowed for expert feedback on the two candidate VFT hierarchies, which was crucial to the establishment of parent issues and the development of a *go/no go* filter for the hierarchy. Of the eight experts who claimed preference for one hierarchy over the other, six selected the version established by this research. Aside from their assertions that it presents a better conceptual representation of the decision situation, all six experts showed preference for a model that separates feasible force mixes from infeasible mixes *prior to* the scoring. Such separation allows decision makers to accept a group of feasible mixes and bypass the extrinsic scoring function of the decision support tool if they so choose. The final value hierarchy representing this decision situation is presented in Figure 13.

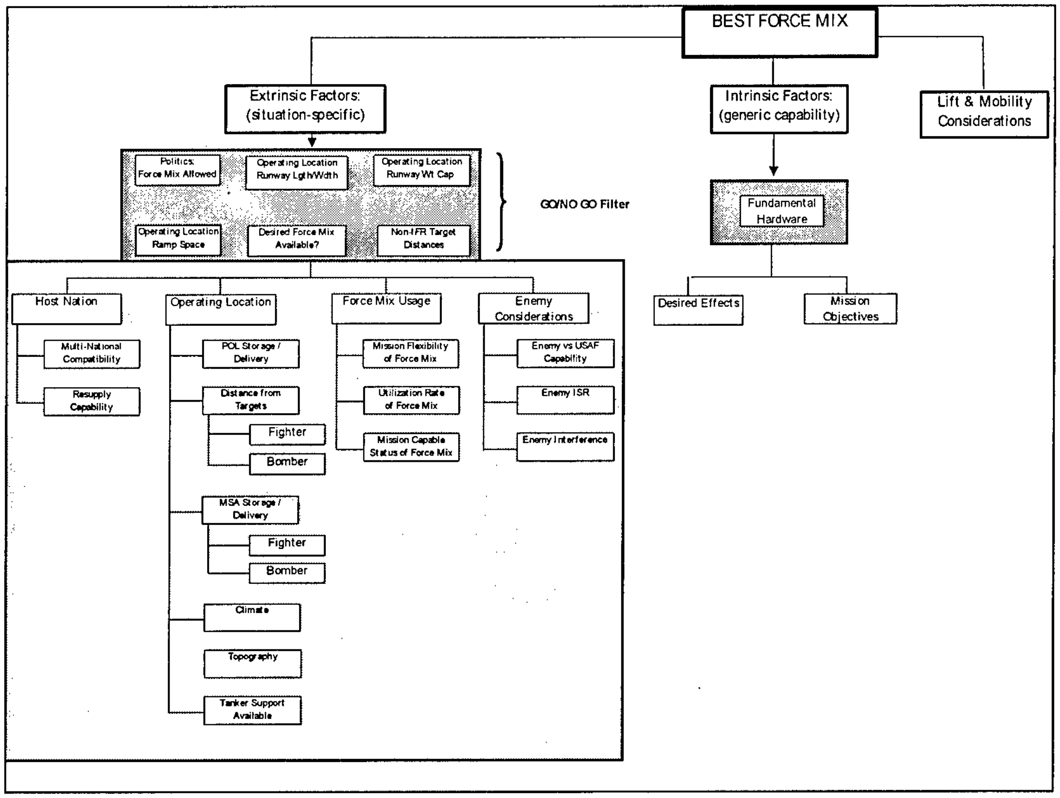


Figure 13: Final VFT value hierarchy

As Figure 13 shows, the four parent issues are Host Nation/Base, Operating Location, Force Mix Usage, and Enemy Considerations. Establishment of these parent issues was important to the weighting of individual factors within the model, and to the sensitivity analysis on the model weights which is discussed later. The *go/no go* filter was placed above the scored factors in the hierarchy to represent its importance as a determinant of which force mixes will be scored.

The second and third rounds of modified Delphi study established the parent issue weights and global weights for the factors within the model. These rounds were in the

form of email questionnaires. Instructions for the questionnaires were provided and can be viewed in Appendix F. A sample of the questionnaire is shown in Appendix G.

Elicitation of pairwise comparisons of relative importance among all of the scored factors generated one complete set of weights for each of the four agencies (ACC, AEFC, CADRE, SouthAF). These weights were averaged and re-submitted to the experts, who were given an opportunity to revise or defend their previous inputs. The result is a set of global weights representing the relative importance of each scored factor within the model. It is important to note that, just as the CentAF *value functions* (elicited from previous research) are included in the model, the CentAF *global weights* are likewise included, averaged into the total.

The complete set of global weights and parent issue weights, along with the lowest and highest weights elicited, are presented in Table 5.

Research Question 3 asked: How are these factors quantified, and what are the relationships between them? This research question has been satisfied. Extrinsic factors are best quantified by placement into a VFT value hierarchy, with the assignment of individual single-dimension value functions (SDVF's) and global weights to each. The hierarchy is presented in Figure 13, and the global weights are provided in Table 5. However, *individual agency* SDVF's, while specific quantifications of each factor, are not considered the final quantifications of each. It is the USAF-wide SDVF's discussed in the next section that are the driving force behind the model.

Table 5: VFT model weights

AVERAGE WEIGHTS	LOW	AVG	HIGH	ROUNDED
MN Compatibility	0.018786	**0.049763**	0.090226	**0.049**
Ability to Resupply	0.00738	**0.049823**	0.174	**0.048**
POL Storage	0.067007	**0.080772**	0.098626	**0.08**
Fighter Distance	0.019145	**0.030507**	0.049313	**0.03**
Bomber Distance	0.006382	**0.026225**	0.03	**0.026**
MSA: Fighter	0.024657	**0.06328**	0.179999	**0.063**
MSA: Bomber	0.012328	**0.056241**	0.179999	**0.056**
Climate	0.003522	**0.018234**	0.03	**0.018**
Topography	0.015	**0.031175**	0.067	**0.031**
Tanker Support	0.022336	**0.062375**	0.090226	**0.062**
Force Mix Flexibility	0.011272	**0.036324**	0.067	**0.035**
Force Mix Utilization	0.011272	**0.031337**	0.051	**0.03**
MC Rate	0.045	**0.072559**	0.107211	**0.072**
Enemy vs USAF Capability	0.09	**0.210197**	0.394505	**0.209**
Enemy ISR	0.03	**0.095283**	0.178685	**0.095**
Enemy Interference	0.09	**0.096773**	0.134014	**0.096**
				1
PARENT ISSUES, AVG WTS	LOW	AVG	HIGH	
Host Nation	0.025831	**0.097**	0.120301	
Basing	0.215061	**0.366**	0.625002	
Usage	0.078901	**0.137**	0.180451	
Enemy	0.209999	**0.4**	0.624633	
		1		

Phase IV: Development of the Decision Support Tool

Phase I confirmed the separation between extrinsic and intrinsic factor types and developed their definitions. It also established which specific extrinsic factors are important. Phase II established the most appropriate method for modeling the problem. Phase III confirmed the final value hierarchy, final parent issue weights and global weights, and the agency-specific SDVF's for each of the scored factors. Phase IV of the research integrated all of the results into a viable decision support model.

The primary purpose of Phase IV was two-fold: to develop an actual decision support tool that provides *USAF-wide applicability* (research question 5), and to provide an accurate mathematical representation of the relationship between intrinsic value and extrinsic value (research question 6).

The developed single-dimension value functions (SDVF's) are the heart of the VFT decision support tool. It is these values that reflect the subjective judgements of the participating experts in a quantitative fashion, allowing for quantification of the entire decision situation.

Single dimension value functions were elicited from AEFC, ACC, CADRE, SouthAF, and CentAF (the last via prior research). This produced five SDVF's for each extrinsic factor—a contribution of 80 for the model. Note that the previous research had established only 16 such SDVF's [Buzo, 2000]. Successfully combining these 80 SDVF's (five per factor) into 16 (one per factor) was important to establishing USAF-wide applicability for the model.

For each factor, the individual SDVF's were analyzed to determine which involved the highest number of functions in its makeup. For example, one SDVF might have a piecewise linear function for the first third of its range, then an exponential function for the next third, and finally either full (1) or zero value for the final third, with no function. If this SDVF had more of these components than any of the others (for this factor) then the final USAF-wide SDVF must possess at least that many components. Once the number of required components had been established, average midpoints among all five SDVF's—for each of the component ranges—were determined. Finally, the appropriate functions, either exponential or piecewise linear, were input for each

component range, producing an overall USAF-wide SDVF that accurately represents the preferences of the decision makers. This was repeated for all 16 factors. That done, the model contains a total of 96 SDVF's. The 16 USAF-Wide SDVF's produced by this process can be used in computing the extrinsic values of force mixes—with USAF-wide applicability. However, any of the original sets of agency-specific SDVF's can also compute the extrinsic value of a candidate force mix.

Research questions 3 and 5 have been satisfied. How are these factors quantified and what are the relationships between them? They are quantified via single-dimension value functions within an additively-independent VFT value hierarchy with global weights determining relative importance. Can the research results be applied USAF-wide? The extrinsic factors have been quantified with USAF-wide applicability through the averaging of their SDVF's (and the keeping of all *single agency* SDVF sets within the model), and the global weights have USAF-wide applicability because the three-round modified Delphi study produced weights that proved robust during sensitivity analyses.

Each of the USAF-wide single-dimension value functions, along with the values for the components of the individual SDVF's that generated them, can be seen in Appendix H. An important consideration is that all of the 96 SDVF's and all of the *single-agency* parent issue and global weights remain within the model. This gives future analysts or decision makers an opportunity to *choose* the group of experts whose SDVF's and weights they might prefer, if they disagree with the USAF-wide composition or if they just want a more theater-specific slant on decision making (such as CentAF SDVF's for a Southwest Asia engagement). This establishes a *family* of VFT models in one, further enhancing the claims of applicability throughout the entire Air Force.

The entire VFT decision support tool is in Microsoft Excel spreadsheet form. The "Scored Forces" sheet contains the formulas for translating straw model, SDVF, and constraint (*go/no go* filter) inputs into overall force mix extrinsic scores. Each SDVF is a combination of *IF* statements incorporating all of its value curve components. The "Scored Forces" sheet multiplies the SDVF's by their respective *go/no go* filter scores and their global weights for all 16 factors, for all the candidate force mixes. The individual Excel formulas for each of the 16 extrinsic decision factors can be seen in Appendix N.

Linked to both the "Scored Forces" sheet and the "Straw Model" sheet is the "Constraint Filter" sheet (the *go / no go* filter). This filter improves upon previous research in that it calculates the model constraints based upon *each aircraft type* within a force mix, rather than just on the force mix as a whole. Therefore, if one aircraft type is infeasible (i.e., not allowed for political reasons), then the entire force mix is infeasible. This does not omit from consideration the otherwise qualified aircraft within the force mix because they are scored as parts of other candidate force mixes. Another improvement is that some of the constraints, such as unrefueled distance from targets, are linked to and derived from the straw model.

The "Straw Model" sheet is a necessary component of the decision model because it provides the avenue for testing. The straw model developed for this research incorporates a matrix of five weapons platform types and three required aerospace missions. Capability can be set as a requirement and combinations of forces that meet the requirements can be tabled and their intrinsic suitability computed (with notional data). This construction parallels the makeup of concurrent AFIT research into the scoring of

intrinsic value and allows for continuity of future ALP research. Also, its format is appropriate for the introduction of real world, campaign-specific data by decision makers. The previous straw model was comprised essentially of a single, escalating force mix, with random individual scores for each force mix as inputs into the extrinsic scoring sheet.

Another advantage of the straw model is that the *candidate operating location* determines many of the values. This set-up allows for more than just greater realism, it allows for decision makers to *score potential operating locations* against force mixes. This was not a goal of the research, but goes far in enhancing ALP and M-R VAT development. With the ALP capability of generating real-time logistics information for all operating locations worldwide, any such location could be instantaneously scored by entering its information into the model.

The model also contains individual sheets for each of the 16 extrinsic decision factors. Graphs are provided for all individual agency SDVF's as well as each USAF-wide SDVF. Again, Appendix H shows the graphical representations for the USAF-wide functions. The model contains a number of additional sheets pertaining to the hierarchy and various sensitivity analyses, but only one more is mentioned here.

The parent issue weights and global weights are calculated on the "Computing Weights" sheet, which is linked by formula to the "Scored Forces" sheet. One can alter the weight of any parent issue and the others will adjust automatically in proportion to each other. Any change in the parent issue weights is immediately reflected in the "Scored Forces" sheet, as is any change in the straw model inputs, operating location inputs, USAF-wide SDVF's, or the constraints. This complete linkage makes this

decision support tool ready now for graphical user interface development. Moreover, the tool is ready now for input of real-world data on operating locations and candidate force mixes that will instantaneously generate real-world extrinsic value of those force mixes.

Three sample sheets from within the VFT decision support tool are presented, without formulas due to space limitations, in Appendix K.

The sixth and final research question called for an accurate mathematical representation of the relationship between extrinsic value and intrinsic value. While this research effort focused on determining the *extrinsic* value of force mixes only, parallel AFIT research was being conducted on the *intrinsic* factors [Wakefield, 2001]. However, it was the responsibility of this research to attempt an integration of the two types of value. That said, *three* related measures of value apply to the overall effort: capability, suitability, and extrinsic value.

Capability is defined under this research as *the number of sorties required within each aerospace mission type that is required by the joint or theater commander at a specific point in time.* For example, on day six of a particular campaign, the commander may require 10 air interdiction sorties, 20 air-to-ground sorties, 5 strategic bombing sorties, and 1 combat search and rescue sortie. This is the *capability* requirement. Suitability then measures *each aircraft type's relative ability to accomplish the required aerospace missions*. For example, Fighter X may have suitability scores of .8 for air interdiction, .5 for air-to-ground, and .1 each for strategic bombing and combat search and rescue. These numbers are notional because research into determination of these actual values is beyond the scope of this research.

Capability and suitability are both considered independent dimensions of *intrinsic* value. The remaining research question (question 6) required investigation of how all three dimensions of value can be combined into a single analytical approach.

In-person interviews had determined that participating experts preferred, slightly, *intrinsic* value to *extrinsic* value. With the development of the straw model (under the premise of intrinsic value resulting from suitability and capability), preference for intrinsic value is straightforward—force mixes that do not first meet the capability requirements are not scored. Using attainment of required capability as a *qualifier*, the task remaining was to address how to best combine a weapons platform's *suitability* with its *extrinsic* (situational) value.

As a notional starting point for this investigation, it was decided to follow up on the relationship initially proposed as a default approach by Buzo, a straight multiplicative relationship [Buzo, 2000] where the intrinsic score is just multiplied by the extrinsic value (as determined by the VFT model).

A multiplicative relationship is superior to an additive relationship—in this situation—for two reasons. First, suitability scores and extrinsic values will most probably be in different units of measurement. Second, the *go/no go* filter of the extrinsic model disqualifies some force mixes from consideration, giving those mixes overall scores of zero. An additive relationship could result in disqualified force mixes holding considerable value when combined with the suitability score, which would be undesirable. A multiplicative relationship yields an overall, combined score of zero for those disqualified mixes.

The utility of this proposed multiplicative relationship was tested during the sensitivity analysis (internal and external) discussed next. Research question 6, concerning the intrinsic/extrinsic relationship, will be revisited after presentation and discussion of the sensitivity analysis results.

The following section discusses internal sensitivity analysis (on the global weights and the averaged, USAF-wide SDVF's), and external sensitivity analysis (on the impact of the VFT model on intrinsically scored and ranked force packages).

Internal Sensitivity Analysis

The first area of internal sensitivity analysis was the testing of the impact that a *single agency* SDVF for a single factor would have on the results of the VFT decision support tool. The purpose was to validate the averaged *USAF-wide* SDVF's as accurate representations of the group's point of view.

The decision support model was run 16 times, once each for every scored extrinsic factor. For each running, a different factor was selected, with the most dissimilar single agency SDVF replacing the USAF-wide SDVF. Each running of the model produced its own ranking of force mixes. The top four ranked force mixes from the initial model results (with all of the USAF-wide SDVF's) were tracked throughout the process.

The results of this sensitivity analysis validated the use of USAF-wide SDVF's. None of the top four ranked force mixes changed their rankings for any of the 16 model runs. Graphical representation of the sensitivity analysis, with narrative, can be found in Appendix J. Extending the analysis to all of the ranked force mixes, there were 512

opportunities for force mixes to change their rankings (32 mixes scored 16 times each). Of the 512 chances, only four changes in rank occurred. These changes were among force mixes that were quite similar in basic makeup—almost identical. Therefore, the conclusion is that the USAF-wide SDVF's are robust representations of the values of the individual agencies involved.

The second internal sensitivity analysis had the purpose of validating the parent issue weights within the decision support tool. Each parent issue weight was changed, *one at a time*, incrementally between a value considerably lower than the lowest weight received by any expert and a value considerably higher than the highest weight received. With each change in a particular parent issue weight, the other three weights were formulated to change in proportion to each other, keeping the sum of all weights equal to 1. This effort mirrored the sensitivity analysis conducted in prior research [Buzo, 2000], whereby the top three ranked force mixes were tracked throughout the process.

Within the range of weights received, the parent issue Operating Location had just one change in the most preferred among the top three ranked force mixes. This change in rank, force mix #18 overtaking force mix #19 as the most preferred, occurred very near the value of the final weight used within the final model (.366).

The Host Nation parent issue showed no change in ranks among the top three force mixes within the range of weights received. This also occurred for the other two parent issues, Force Mix Usage and Enemy Considerations.

Changes in ranks did occur among some force mixes that had been ranked lower, and among the top three force mixes *outside* the range of weights received. This lends evidence as to the robustness of the averaged weights used for the model, as

representations of the expert participants' group judgements. It also lends support to the position that the weights are *not* unimportant if taken to extreme ranges outside the range of weights received or if the force mixes are otherwise valued similarly.

The four graphical representations of this sensitivity analysis are presented in Appendix I.

In summary, the internal sensitivity analysis showed *both* the averaged parent issue weights and the averaged USAF-wide SDVF's to be satisfactorily robust. This is reassuring, particularly for the SDVF's, because the averaging of such functions could be controversial. In this case, both averaging methods meet the requirements of the decision situation.

External Sensitivity Analysis

The external sensitivity analysis had the purpose of determining whether the VFT decision support tool has *practical significance* for the ALP and the M-R VAT. Specifically, this sensitivity analysis set out to determine the impact that extrinsic scoring provided by the VFT model has on an intrinsically scored and ranked set of force mixes, *using the multiplicative relationship proposed earlier.*

In line with the premise that only those force mixes that meet basic capability requirements are scored intrinsically (suitability scores), the straw model was set up for capability requirements of 10 AA, 20 AG, and 2 PB missions, respectively. The five aircraft types were then given various notional suitability scores for each mission type. Fifty-one combinations of force mixes were tabled, all of which met the basic capability requirements. The number of each aircraft, per type, that is assigned to fill a mission

capability is multiplied by the suitability score (that type against that mission). A notional (but reasonable) matrix of suitability scores was used in conjunction with Wakefield's parallel work on intrinsic value [Wakefield, 2001]. A force mix's suitability score under this technique is simply the sum of each aircraft type's suitability scores for the missions filled. For example, 10 of aircraft FA may be assigned against mission AA. With FA given a suitability score of .8, the score for this assignment of forces is 8. All such assignments within a force mix are summed to gain a total intrinsic value for the force mix.

With the straw model established, force mixes were scored extrinsically against the VFT model. The pre-determined intrinsic value and newly-computed extrinsic value were then multiplied to produce an overall value. Three ranks were constructed: intrinsic, extrinsic, and combined. Once this baseline was established, the sensitivity analysis involved alteration of the straw model and the VFT model to extreme values *within* each, with subsequent comparisons of impact.

The intrinsic value computed by the straw model was held constant for the first set of comparisons. All of the notional *extrinsic* multipliers within the VFT model were set at extreme differences of .9 and .1 for different aircraft types in order to create a greater difference in final extrinsic values between force mixes. With greater extrinsic differences generated among the force mixes, these extrinsic values were multiplied against the intrinsic values, with the new rankings recorded. This process was repeated for internal values of .8 and .2, .7 and .3, .6 and .4, and .51 and .49 within the VFT model. As the VFT model produced tighter and tighter differences between scored force mixes, the impact of each iteration upon the *intrinsic* rankings (held constant) could be

measured. An excerpt of the rank results is presented in Table 6 (complete tabular rankings are included in Appendix O).

Table 6: External Sensitivity Analysis (intrinsic held constant)

Sensitivity Analysis on Impact of VFT Model
with INTRINSIC *internal* values held constant

MIX	Independent Intrinsic Rankings	Combined (overall) Rankings with internal extrinsic at .51 and .49	Combined (overall) Rankings with internal extrinsic at .6 and .4	Combined (overall) Rankings with internal extrinsic at .7 and .3	Combined (overall) Rankings with internal extrinsic at .8 and .2	Combined (overall) Rankings with internal extrinsic at .9 and .1
Mix 1	1	1	1	6	13	18
Mix 13	2	2	2	8	16	22
Mix 16	3	3	4	10	18	24
Mix 4	4	4	5	14	22	29
Mix 9	5	5	9	15	20	25
Total rank changes (out of 51)		18	43	44	47	51

As can be seen in Table 6, as the range of values within the VFT model approach their most extreme differences, the model's impact upon intrinsically scored and ranked force mixes is profound. Every one of the 51 scored force mixes changes its relative rank when combined with its extrinsically scored value. However, even at the tightest internal ranges in value, the VFT model has a clear impact, changing none of the top five but changing 18 of the 51.

The second set of comparisons was accomplished with the extrinsic VFT model results held constant and the *intrinsic* values adjusted to their extremes. For the first test, the FA and FC aircraft were given .9 suitability for AA missions and the FB aircraft given .1. These scores were reversed for the AG mission. The B1 aircraft was given .9 suitability for the PB mission, with the B2 aircraft given .1. With these extreme values entered, the resultant intrinsic scores for the force mixes were multiplied by the *extrinsic* values that had been held constant. This process was repeated for suitability values of .8

and .2, .7 and .3, .6 and .4, and .51 and .49. Again, the impact of each iteration was recorded. An excerpt of the rank results is presented in Figure 7 (complete tabular rankings are included in Appendix O).

Table 7: External Sensitivity Analysis (extrinsic held constant)

Sensitivity Analysis on Impact of VFT Model
with EXTRINSIC *internal* values held constant

MIX	Independent Intrinsic Rankings	Combined (overall) Rankings with internal intrinsic at .51 and .49	Combined (overall) Rankings with internal intrinsic at .6 and .4	Combined (overall) Rankings with internal intrinsic at .7 and .3	Combined (overall) Rankings with internal intrinsic at .8 and .2	Combined (overall) Rankings with internal intrinsic at .9 and .1
Mix 1	1	1	1	1	1	1
Mix 9	1	5	2	2	2	2
Mix 13	3	3	4	4	4	4
Mix 16	3	2	3	3	3	3
Mix 21	3	6	5	5	5	5
Total rank changes (out of 51)		47	39	35	35	35

Table 7 shows the VFT model's impact when the differences in *intrinsic* internal values are extreme. As can be seen, the VFT model still changes some of the pre-determined ranks. As the internal values within the straw model tighten, the impact of the VFT model increases substantially. At the tightest internal values of .51 and .49, 47 of the 51 force mixes change relative ranks. At the loosest internal values of .9 and .1, the extrinsic multiplier still results in 35 changes in rank.

Sensitivity Analysis and the Combined Value Measure

Given realistic values within each, the VFT decision support tool clearly impacts the rankings of intrinsically scored force mixes. Table 8 shows intrinsic ranks and scores, extrinsic ranks and scores, and the results of combining the two multiplicatively. This

table reflects the impact of the VFT model when both the model and the straw model have relatively close *internal* values (.6 and .4 for intrinsic, closer than .51 and .49 for extrinsic).

Both the internal and external sensitivity analyses provided valuable indicators as to the robustness of the weights used and the USAF-wide SDVF's, as well as the impact the VFT decision support tool can have on intrinsically-scored candidate force mixes.

The insights gained by conducting the sensitivity analyses using a multiplicative process and a notional, matrix-driven straw model (that produced notional suitability scores and ranks) helped to generate the most appropriate answer to research question 6: How can the now-quantified extrinsic factors be effectively combined with the intrinsic factors to develop an overall asset set utility or value?

The *intrinsic* rank structure is linear and scalar, just the opposite of the *extrinsically-generated* scores/ranks that are derived from this research's qualitative concept (VFT)—which are nonlinear and non-scalar. The distinction between intrinsic value and extrinsic value is more than just conceptual; extrinsic and intrinsic each comprise *distinct dimensions* of value. In line with the dimensional distinction, both the straw model of this research and the algorithm under development by Wakefield's parallel research [Wakefield, 2001] produce *suitability* scores in units *dissimilar* to the zero-to-one *extrinsic* scores produced by the VFT model.

The main point is that this research produces *extrinsically*-scored force packages but cannot *intrinsically* score those packages. Conversely, Wakefield's parallel research has developed an algorithm that *intrinsically* scores force packages and establishes *a set* of non-dominated (pareto optimal) force mixes [Wakefield, 2001]. The force mixes

within Wakefield's pareto optimal set are all *essentially tied*, with no means provided for the decision maker to select the most appropriate force mix from the set. This is a fortuitous situation for the VFT model of this research.

In this light, the simple *multiplicative* approach is the most appropriate method for integrating intrinsic value and extrinsic value—*given that a set of pareto optimal force mixes have been designated and the VFT model is used as the lower echelon tie breaker.* With this relationship, the progression through a force mix selection starts with the *capability* requirements, goes on to determination of the optimal set of *most suitable* force mixes, and finally, has the *extrinsic value* break the tie among those pareto optimal force mixes.

Research question 6 is satisfied by this multiplicative, tie-breaking relationship that lends slight preference to the *intrinsic* value of force mixes, as desired by the experts. Furthermore, this representation generates overall scores of zero for those infeasible force mixes and overcomes differences in the units of measurement (as well as dimensional differences).

Table 8 presents the results of a single external sensitivity analysis, and illustrates the multiplicative relationship between extrinsic and intrinsic values. Although *none* of the intrinsically scored/ranked force mixes are tied (as would be with a pareto optimal set), they nonetheless change relative ranking when multiplied by the VFT model results.

In summary, this research developed a VFT decision support tool that uses robust issue weights and robust *averaged* SDVF's. The tool contains a *family* of models representing the expertise of five agencies, and incorporates a multiplicative, tie-breaking relationship with the intrinsic values generated by parallel AFIT research.

Table 8: Extrinsic impact on intrinsic value

MIX	Extrin @ Typical	Rank	(suitability) Intrin @ .6 and .4	Rank	Multiplic. Result	Rank
1	0.713534	**15**	19.2	**1**	13.69985	**1**
2	0.714978	**8**	13.2	**44**	9.437715	**44**
3	0.71603	**2**	12.8	**50**	9.165182	**50**
4	0.714309	**9**	18.8	**7**	13.42902	**7**
5	0.710151	**34**	15.2	**21**	10.7943	**23**
6	0.70924	**38**	13.2	**44**	9.361965	**45**
7	0.711153	**25**	14.8	**37**	10.52506	**42**
8	0.709751	**35**	12.8	**50**	9.084811	**51**
9	0.710476	**30**	19.2	**1**	13.64113	**2**
10	0.712788	**16**	15.2	**21**	10.83438	**22**
11	0.711142	**26**	18.8	**7**	13.36946	**8**
12	0.714035	**10**	14.8	**37**	10.56772	**37**
13	0.713743	**12**	19	**3**	13.56112	**4**
14	0.715651	**4**	13	**46**	9.303466	**46**
15	0.715283	**5**	13	**46**	9.298677	**47**
16	0.71402	**11**	19	**3**	13.56638	**3**
17	0.710439	**31**	15	**28**	10.65658	**29**
18	0.709478	**36**	13	**46**	9.223216	**48**
19	0.710439	**31**	15	**28**	10.65658	**29**
20	0.709478	**36**	13	**46**	9.223216	**48**
21	0.710648	**27**	19	**3**	13.50231	**5**
22	0.713594	**13**	15	**28**	10.7039	**25**
23	0.710648	**27**	19	**3**	13.50231	**5**
24	0.713594	**13**	15	**28**	10.7039	**25**
25	0.715222	**6**	15.2	**21**	10.87138	**21**
26	0.716797	**1**	14.8	**37**	10.60859	**35**
27	0.715707	**3**	15	**28**	10.7356	**24**
28	0.711992	**23**	17.2	**9**	12.24627	**9**
29	0.712621	**20**	16.8	**13**	11.97203	**14**
30	0.712379	**22**	17	**11**	12.11044	**10**
31	0.70073	**50**	15.2	**21**	10.65109	**31**
32	0.710606	**29**	14.8	**37**	10.51697	**43**
33	0.70368	**45**	15	**28**	10.5552	**38**
34	0.71145	**24**	16	**17**	11.3832	**16**
35	0.704337	**44**	16	**17**	11.2694	**19**
36	0.708184	**40**	15	**28**	10.62276	**34**
37	0.704945	**43**	16.2	**15**	11.42011	**15**
38	0.701729	**49**	16.2	**15**	11.36802	**17**
39	0.700554	**51**	15.2	**21**	10.64843	**32**
40	0.71521	**7**	15.8	**19**	11.30033	**18**
41	0.710439	**33**	15.8	**19**	11.22494	**20**
42	0.712593	**21**	14.8	**37**	10.54638	**41**
43	0.705602	**41**	15	**28**	10.58403	**36**
44	0.70902	**39**	15	**28**	10.6353	**33**
45	0.705602	**41**	17	**11**	11.99523	**12**
46	0.702531	**46**	15.2	**21**	10.67847	**27**
47	0.702531	**46**	15.2	**21**	10.67847	**27**
48	0.702531	**46**	17.2	**9**	12.08353	**11**
49	0.712772	**17**	14.8	**37**	10.54903	**39**
50	0.712772	**17**	14.8	**37**	10.54903	**39**
51	0.712772	**17**	16.8	**13**	11.97457	**13**

*Shading denotes a rank change

VI. Conclusion

Introduction

Chapters I and II discussed the Defense Advanced Research Projects Agency's Advanced Logistics Project (ALP), stating that the ALP will provide near real-time logistics information from Department of Defense and Allied organizations throughout the world. Campaign planners will have an opportunity to compare deployment scenarios with accurate, up-to-date information and respond to crises with greater efficiency than previously possible.

As a logistics-centered computing architecture, the ALP's overriding focus is on reducing both the deployment timeline and the deployment footprint. The Mission-Resource Value Assessment Tool (M-R VAT) is designed to be a front-end component to the ALP architecture that will reduce both the timeline and the footprint by enabling selection of the best value assets at the right time.

The primary goal of this research was to provide a USAF-wide decision support tool in support of the M-R VAT that quickly identifies the best possible force mixes based upon their extrinsic values. The secondary goal was to determine the most appropriate mathematical relationship in combining extrinsic and intrinsic values into overall force mix values. To accomplish these goals, six research questions were answered:

1. Can the factors affecting force mix selection in response to theater crises be clearly categorized as extrinsic and intrinsic, and can these categories be clearly defined?

2. What extrinsic factors are important to campaign planners when selecting aircraft force mixes in response to theater crises?

3. How are these factors quantified, and what are the relationships between them?

4. How should these factors and the relationships between them be modeled?

5. Can the research results be applied USAF-wide?

6. How can the now-quantified extrinsic factors be effectively combined with the intrinsic factors to develop an overall asset set utility or value?

A four-phase methodology was implemented to address these six research questions, and is presented in Table 4 of Chapter IV.

The first phase of research consisted of in-person interviews with campaign planning experts throughout the USAF, using the Critical Decision Method, and content analysis of relevant USAF and Department of Defense publications on Joint Planning. The purpose of this phase was to establish the conceptual separation of extrinsic and intrinsic decision factor categories, to define these categories, and to elicit all of the extrinsic decision factors necessary for consideration during crisis action campaign planning. The experts provided unanimous agreement on the separation of extrinsic and intrinsic decision factors, helped to establish definitions for each, and provided 22 extrinsic factors important to force mix selection. The content analysis likewise presented extrinsic decision factors, as well as a set of intrinsic factor parent issues (see Figure 1, page 19). Phase I of the research satisfied questions 1 and 2.

Phase II of the research methodology was comprised solely of a literature review of the Decision Analysis (DA) field to determine the most appropriate DA approach with which to model this decision situation. Several DA methodologies were investigated and

compared to the requirements of this decision situation, resulting in the selection of Value Focused Thinking as the most appropriate technique. This effort improves upon previous research involving this decision situation, in which no meaningful comparisons of DA techniques against each other or against the decision situation were accomplished. Phase II results satisfied research question 4.

The third phase of methodology incorporated a modified Delphi in-person and email study, comprising three rounds. The three rounds of the modified Delphi study helped to establish the value hierarchy (necessary to creating the VFT decision support tool). Additionally, they established definitions and ranges for each of the extrinsic decision factors, led to the creation of 64 single-dimension value functions representing the expert judgements of the study participants, and generated all of the global and parent issue weights for use in the final VFT model. Completion of Phase III satisfied research question 3.

Phase IV of the research methodology was reserved for the building of the VFT decision support tool. The successful *averaging* of individual agency single-dimension value functions (SDVF's) into robust USAF-wide SDVF's was the final step in satisfying research question 5. Further satisfaction of research question 5 is the inclusion of a *family of models* within the single VFT framework, allowing flexibility in its application. Finally, the development of a multiplicative, tie-breaking relationship, between this extrinsic VFT model and an intrinsically-scored set of pareto optimal force mixes, answers research question 6.

Summary of Research Advancements

The primary advancement provided by this research over previous research is the *USAF-wide applicability* of the decision support tool. The six research questions notwithstanding, USAF-wide applicability was the primary goal of this research. It is attained via the diversity and breadth of experience of the subject matter expert pool, combined with the averaging of individual single-dimension value functions, and the inclusion of a family of models representing five agencies and the USAF overall.

The second advancement is the investigation and evaluation of a large number of alternate Decision Analysis (DA) techniques. Previous research had attempted no such endeavor. The results of the DA investigation validated VFT as the most appropriate technique for modeling and addressing this decision situation.

The establishment of an accurate mathematical representation of the *extrinsic-intrinsic value relationship* constitutes the third advancement. With intrinsic value scored and a set of pareto optimal force mixes established, simple multiplication by the respective extrinsic values *instantaneously breaks the ties*, leading to significantly reduced force mix selection timelines and the simplified selection of best overall force mixes.

The fourth significant advancement is the *straw model* that is driven by both capability requirements and operating location characteristics. The capabilities-driven aspect allows for the 3x5 matrix of aircraft types and aerospace missions to generate candidate force mixes that are relatively equal in number and absolutely equal in basic capability, differing only by their suitability scores. The operating location aspect allows for operating location-specific data to be input which affects the value of candidate force

mixes while also allowing for different operating locations to be scored against constant sets of force mixes. As simply a test set, this would not normally warrant consideration as an advancement. However, its structure readies the VFT tool now for decision maker input of real-world data and subsequent real-world force mix selection.

Another advancement is the inclusion of 96 single-dimension value functions (versus the 16 of previous research) representing the USAF-wide perspective and perspectives from AEFC, CADRE, SouthAF, CentAF, and ACC. Combined with the inclusion of individual issue weights as determined by each agency, any of the five agencies' expertise (or the USAF-wide expertise) can drive the model.

The go/no go filter is a conceptual and practical improvement that not only provides feasible sets of force mixes prior to extrinsic scoring, but is linked by formula to operating location characteristics and straw model aircraft type characteristics.

Finally, this research remedied a flaw in the original VFT decision support tool formulation concerning bomber and fighter distances from targets and munitions storage (MSA) area decision factors. Because bombers and fighters are scored *separately* for distance from targets and MSA, absence of either fighters or bombers in a given force mix could lead to erroneous force mix scoring. For example, if no bombers were included in a candidate force mix, its straw model score for that factor would be zero. The SDVF formula would then translate that zero to full value for the decision maker because bombers would be *zero miles from targets*. The force mix's value would be artificially inflated. This situation is remedied by allowing the global weights for each of these factors to be complimentary between fighters and bombers based upon their respective percentages (in number of aircraft) of the total force mix.

Conclusions

This research shows that the collective, subjective judgements of subject matter experts can be combined into a viable, quantitative decision support tool for the selection of best force mixes during crisis action campaign planning. Moreover, it shows that dissimilar single-dimension value functions from several sources can be effectively and robustly combined into overall single-dimension value functions that accurately represent the views of all involved. The technique for combining single-dimension value functions was not found in literature during the course of this research, and may be unique in this application.

An important aspect of the developed VFT decision support tool is that it scores the extrinsic values of competing force mixes almost instantaneously, in a format that is already set up to receive the intrinsically scored and ranked force mixes that result from concurrent AFIT research.

Furthermore, this research shows that the VFT decision support tool has a significant impact on the rankings of force mixes that have been previously scored and ranked intrinsically.

The bottom-line value of this VFT decision support tool is that, given a set of intrinsically scored force mixes, it can almost instantly produce *overall* values for each candidate mix and subsequently break the ties among force mixes that have been optimized.

Limitations

The primary limitation of this decision support tool is that it scores only the *extrinsic* value of candidate force mixes. Although it is formatted to produce overall force mix values, it must do so with force mixes that have already been scored and ranked intrinsically.

Another limitation is the size of the subject matter expert pool and the number of agencies involved in the Phase III portion of study. This research focused on the opinions of experts within the continental United States, ignoring expertise that might be provided from planners in overseas commands. The possibility exists that inputs from overseas commands could change the single-dimension value functions and global weights within the VFT model. Although sensitivity analyses might prove such inputs inconsequential, the limitation exists nonetheless.

Recommendations

It is recommended that this VFT decision support tool be fully incorporated into the M-R VAT as a front end force mix value determinant for the Advanced Logistics Project. It provides an avenue for campaign planners to quickly evaluate the effects of extrinsic considerations on candidate force mixes. Moreover, the model's format and formulas are consistent with ongoing AFIT research and qualify it as the *template* upon which the M-R VAT can be based.

The VFT decision support tool can run now in a real-world environment. However, it is built upon notional data, necessitating the introduction of actual extrinsic data before it can be applied operationally.

Further Research

The additional research most necessary to the success of this VFT decision support tool is the collection of real-world data as it relates to the *extrinsic* value of individual weapons platforms. For example, what is the ratio of consumption to resupply for an F-16C assigned to contingency operations at Base X, or what is the Munitions Storage Area requirement for an A-10?

Further research is also necessary to determine the most effective integration of this decision support tool into the M-R VAT, including its integrative programming and the development of a graphical user interface.

Finally, further investigation is necessary to determine the relationships among *individual factors* within and between the intrinsic and extrinsic categories. Some may not fall entirely within one category or the other. Distinction between the categories (and appropriate definitions) has been established. However, there is a possibility that some of the individual factors may fall within *both* categories.

Summary

The Value Focused Thinking Decision Support Tool developed by this research provides a method to quickly evaluate candidate force mixes for contingency deployments based upon factors that are specific to the situation (extrinsic) rather than to the basic capabilities of the weapons platforms themselves (intrinsic). It provides a means for almost instantaneously computing *overall* force mix values once those force mixes have been valued intrinsically.

The support tool was developed with the expertise of campaign planning experts from Headquarters USAF, Air University, Air Combat Command, Southern Air Forces Command, Central Air Forces Command, the Air Expeditionary Forces Center, Joint Forces Command, Air Force Special Operations Command, RED FLAG, and Fighter Weapons School.

The model incorporates *combined* single-dimension value functions, as well as value functions and weights representing *five* agencies. This combination enhances USAF-wide applicability. It was demonstrated and validated using a capabilities and operating location driven straw model of 51 candidate force mixes. The validation showed all weights, value functions, and the overall model to be robust during internal and external sensitivity analyses.

This research and its resultant VFT decision support tool present a number of advancements over previous research in this area, providing a sound building block upon which ongoing AFIT research in support of the ALP program can be based.

This work is a first step in *quantifying the art* of force selection. Such quantification can allow planners, regardless of experience level, to act and decide crisis action planning issues in a manner consistent with the best planners in today's USAF. This in turn can generate consistency of planning competence across all USAF agencies. Furthermore, these consistent, expert-level decisions could be made in fractions of the time, reducing deployment timelines and footprints while enhancing the USAF's most core competency—warfighting.

Appendix A: Bullet Background Paper

Purpose of this background paper: to provide the respondent with an overview of the topics of discussion to be addressed during the interview.
Purpose of the interview: to obtain knowledge and understanding of the ***process and factors*** considered when selecting certain combat aircraft asset sets for theater deployment.

- USAF now operates under the expeditionary concept
  -- Deploy small contingent of aircraft, 36 fighter and 2-6 bomber assets per set
  -- May be expected to commence aerospace missions immediately upon arrival
  -- Campaign will require several types of aerospace missions, defined in AFM 1-1

- Our purpose is to look ahead *beyond current prepackaged forces*
  -- A tailored force for each scenario
  -- Bring ***everything*** you need but ***only*** what you need
  -- Calculate time-phase requirements, spin up to fight from day zero…no more "closure" of forces

- Please walk through a complete planning process for expeditionary force contingency
  -- Realizing there are several layers of planning and decision-making, *your* views at your level are of prime importance in this study
  -- What is the *fundamental* ***process*** of selecting aircraft types to support a campaign?
  -- In determining the proper aircraft mix to be deployed and in planning for their deployment, what *factors* do *you* look at?

- Focus on identified factors
  -- What makes these important?
  -- Is there anything that may affect this factor…underlying sub-factors?
  -- How do these factors relate to each other and the overall process?

- Conclusion
  -- Any other factors that have not been identified that you feel are important, no matter level
  -- Any important topics we did not discuss?
  -- Any contacts you know of that I should talk to regarding this research?
  -- Soon, a second phase of research will begin. Your continued support will be greatly appreciated
    --- Second phase will be quickly-accomplished email questionnaires to determine values and relative weights of the factors we have identified today—your support will be crucial

- Points of contact for this research
  -- 1st Lt Paul Filcek, AFIT (Paul.Filcek@afit.af.mil)
  -- Lt Col Alan Johnson, AFIT (Alan.Johnson@afit.af.mil), DSN 255-3636 ext 4284
  -- Maj Stephen Swartz, AFIT (Stephen.Swartz@afit.af.mil)
  -- Advanced Logistics Project (ALP) Website (www.darpa.mil/iso/alp)

Appendix B: Interview Script

INTRODUCTION

Good afternoon, Sir. Thank you for taking the time to meet with me today. I am conducting research into the critical factors, or issues, that influence the selection and use of combat aircraft types for contingency deployments. The purpose of this interview is to elicit your knowledge and understanding of the overall process as an expert in the field.

The information you provide will be combined with that of other experts and reported in aggregate. Your information will be confidential in that it will not be traced specifically to you. Only my observers and myself will have access to any identifiable information.

Understanding this obligation of confidentiality, I would like to ask your permission to record this interview. The sole purpose of the recording is to overcome my own lack of shorthand skills. Furthermore, the tape will be reused for subsequent interviews.

I am concerned with not taking more than 45 minutes of your time, so please excuse me in advance for watching the clock and for pushing the pace if we slow down. However, I must stress that the interview is largely unstructured, and any discussions within the context of the interview are encouraged. Do you have any questions before we star?

BACKGROUND

To begin our discussion of the process and the factors, I would like to first set the deployment stage. As you know, we've moved to the expeditionary concept in which the plan is to deploy about 36 fighter and 2-6 bomber assets and their necessary support equipment. These newly-arrived forces will be expected to commence engagement immediately upon arrival, and such engagement of the enemy may require several types of aerospace missions as defined in AFM 1-1 and determined by the theater commander.

Research is currently being conducted in an effort to assist theater commanders and campaign planners in selecting sets of aircraft assets that will provide the *best utility* to the commander, based upon the theater commander's time-phased aerospace mission requirements. The research scenario is that, using a developed mathematical program, asset sets will be identified to provide the commander with the best match-up of aircraft assets to the required missions. Today, these match-ups are based upon a "prepackaged set" of forces, with the capabilities of each individual aircraft matched to specific aerospace missions. Of course, we know that we look at more than just these absolute mission capabilities when planning a deployment. There are many factors of a deployment scenario that may make the selection of one aircraft type preferred over another type, or may negate the possibility of selecting one or more types. Understanding

of the overall process is the focus of today's interview. I am going to ask you a series of questions aimed at obtaining your views and insights.

I must finish the introduction by asking you *not to hold back*; have confidence in your thoughts and feelings on these issues. I am going to many offices in search of a model that applies AF-wide and your experience is very important in the intended scope of this research!

Name:
Duty Position:
Office Symbol:
Email address:
DSN:

1. How many years of experience do you have in the Air Force?

2. With which MDSs do you have operational experience? How many years for each?

3. For which theaters or commands have you done campaign or contingency planning?

4. How many years experience for each?

Those are the required demographic questions. Now we can move on to deployment factors...

5. I would like you to walk me through the planning process for a contingency deployment, one that would be suited to an expeditionary-sized deployment. I know there are many levels of decision-making, but I am interested in *your* views at your level of the process. In determining the proper aircraft asset sets to send, what factors do you look at? Please consider the situations and theaters with which *you are most familiar* and have the greatest recall.

6. Are there any more details or factors, no matter how insignificant you may feel they are?

7. Are these all of the factors you can think of at this time? Please tell me of any others.

8. I have extracted numerous factors from content analysis of regulations/guidance. Do you agree with the existence of these? (*show to subject, compare and contrast, integrate if possible*). *Now show Buzo's*. Please evaluate these factors in like manner.

9. We've established quite a list. It is crucial to have each factor independent of the other factors. Are each of the factors listed independent of the others, or does one or some depend on one or more of the others in its evaluation? I realize that each affects the total outcome, but does a change in any factor affect another factor directly? *(if A changes, does B change because A did?)*

10. Can these factors be divided into two groups, one group pertaining to the quality of the force mix and another group pertaining to the situation? Put another way, are some factors extrinsic to the mission capability of an asset set and other factors intrinsic to that capability?

11. How would you define an extrinsic factor? An intrinsic factor? Here are my definitions *(after the response)*. What do you think?

12. Finally, let's define each of these extrinsic factors. What changes should I make to some of the definitions I've already got?

Thank you VERY much for the interview! Soon, I will begin the second phase of this research that will consist of email questionnaires. Your participation during this phase will be vitally important in determining a decision support tool that is the main point of the study. The next questionnaires will be designed for user-friendliness and fast accomplishment in order to keep the demand on your time as low as possible and to keep your interest in the study.

Again, it has been a sincere pleasure. I thank you very much and look forward to your continued support over the next few weeks.

Appendix C: Extrinsic Decision Factors

Constraints:

1. Politics—Desired Force Mix Allowed?
2. Operating Location—Runway Length and Width Adequate?
3. Operating Location—Ramp Space Sufficient?
4. Operating Location—Runway and Ramp Weight Capacity Sufficient?
5. Operating Location—No IFR, Distance Less Than 700 (Fighters) and 3000 (Bombers) Miles from Targets?
6. Desired Force Mix Available?

Value Function Factors (to be Weighted and Scored):

1. Multi-National Compatibility
2. Beddown Location—Fighter Distance (From Targets, Refueled)
3. Beddown Location—Bomber Distance (From Targets, Refueled)
4. Munitions Storage Area—Fighter
5. Munitions Storage Area—Bomber
6. Ability to Resupply
7. Petroleum, Oil, and Lubricants (POL) Storage/Delivery
8. Tanker Support Provided
9. Operating Location—Topography
10. Operating Location—Climate
11. Mission Capable Status of Force Mix
12. Inter-mission Flexibility of Force Mix
13. Force Mix Utilization Rate
14. USAF vs. Enemy Capability Ratio
15. Enemy Intelligence, Surveillance, and Reconnaissance Impact
16. Enemy Interference Impact (at operating location)

Appendix D: Extrinsic Decision Factors—Definitions and Ranges

(those weighted and scored as value functions)

Title: **Multi-National Compatibility**

Description: The extent to which host nation assets, to include combat aircraft, equipment, spares, and ground support equipment can be incorporated along side and into USAF combat aircraft [Buzo, 2000: 105].

Range of Measurement: 0 – 100 percent for a monotonically increasing function. At 100 percent compatibility, the host nation's candidate operating location for US forces maintains and operates fully compatible assets for 100 percent of the assets in the candidate force mix. USAF combat aircraft can be incorporated into the operating location without bringing in test equipment, spares or excessive maintenance equipment. At 0 percent, none of the host nation assets are compatible with those of the candidate force mix. In this case, campaign planners would need to arrange for sending a complete supply of testing equipment, spares, and maintenance and repair equipment for all combat aircraft sent to the operating location. The entire range of percentages of host nation compatibility is possible.

Title: **Beddown Location—Fighter Distance from Targets, Refueled**

Description: The effectiveness of an individual aircraft type within a candidate force mix is dependent upon its distance from the operating location to its primary mission targets.

Range of Measurement: 0-3000 miles. Given availability of tanker support to provide In-flight refueling (IFR), this is a measure of time-to-target as much as distance—becoming an aircrew effectiveness limitation (and loiter time limitation) as the distance from the operating location to the primary target areas approaches 3000 miles. The entire range of 0 to 3000 miles is possible.

Title: **Beddown Location—Bomber Distance from Targets, Refueled**

Description: The effectiveness of an individual bomber aircraft type within a candidate force mix is dependent upon its distance from the operating location to its primary mission targets.

Range of Measurement: 0 – 7000 miles. This measure is identical to that of Fighter aircraft, with the only difference being the greater range of bomber aircraft.

Title: **Ability to Resupply**

Description: Continuation of aerospace missions from the operating location is dependent upon the ability of USAF forces to resupply equipment, materials, and spares as necessary. The candidate operating location can impact resupply capability and combine with individual aircraft resupply requirements to affect overall mission accomplishment. Aircraft that require smaller amounts of POL, munitions, and other equipment and spares will have a higher independent value than aircraft that require more resources, especially if resources are difficult to come by at the candidate operating location.

Range of Measurement: 0 – 1, ratio of resupply to consumption. As the ratio of resupply to consumption increases to 1, USAF forces' ability to resupply the operating location equals the consumption at that location. As the ratio approaches 0, consumption rates far exceed supply at the operating location. Ratios above 1 are not expected because they would imply an excessive application of resources in time of crisis. The entire range of 0 –1 is possible.

Title: **Munitions Storage Area—Fighter**

Description: Continued combat fighter operations depend on the operating location's ability to store and deliver adequate munitions in a timely manner. Fighters can bring to theater only one load of munitions each. Additional aerospace missions require the operating location to store and deliver munitions.

Range of Measurement: 0 – 100 percent sorties supported. At 100 percent sorties supported, the operating location can store and deliver all of the munitions necessary to conduct the required aerospace operations. At 0 percent sorties supported, the operating location can store virtually no munitions, and the only munitions available are those loaded upon each aircraft upon departure from its home station. The entire range of munitions storage and delivery is possible.

Title: **Munitions Storage Area—Bomber**

Description: Same as Munitions Storage Area—Fighter

Range of Measurement: 0 – 100 percent sorties supported. Same as Munitions Storage Area—Fighter

Title: **Petroleum, Oil, and Lubricants (POL) Storage and Delivery**

Description: The operating location's POL system includes storage and supply from both military and host nation contracted sources. POL capability for a particular force mix must take into consideration the per-sortie POL requirements of each individual aircraft in the force mix mix as well as the daily sortie requirements for each type of aircraft [Buzo, 2000: 107].

Range of Measurement: 0 – 100 percent sorties supported. At 100 percent sorties supported, the operating location's POL system can store and deliver sufficient POL to sustain 100 percent of the projected operational sorties. At 0 percent POL capability, the operating location could support no sorties. Of course, this would disqualify the operating location as a candidate base. The entire range of POL capability is possible.

Title: **Tanker Support Provided**

Description: Depending upon the operating location's distance from enemy targets and the requirements of individual aircraft and aircraft types within a force mix, tanker support may be required or highly desirable.

Range of Measurement: 0 – 100 percent sorties supported. At 100 percent sorties supported, enough tankers are available and included in the deployment plan to support all of the aerospace missions necessary. At 0 percent sorties supported, no tanker support is available for operations. The entire range is possible.

Title: **Operating Location—Topography**

Description: The extent to which natural and man-made land formations in and around the operating location affect the ability of individual aircraft within a force mix to take-off, land, and conduct operations.

Range of Measurement: 0 – 100 percent mission degradation. At 100 percent mission degradation, no sorties can fly in or out of the operating location due to topographical restrictions. Such degradation is a theoretical maximum, since its occurrence would necessitate relocation of combat force mixes. At 0 percent degradation, no sorties are lost to topographical restrictions. The entire range of scores is possible.

Title: **Operating Location--Climate**

Description: The extent to which heat, humidity, wind, and adverse weather conditions affect the ability of force mixes to conduct operations at or around the operating location.

Range of Measurement: 0 – 100 percent mission degradation. As in Topography above, 100 percent degradation would mean that no sorties could be generated, but due to weather conditions here. At 0 percent degradation, all sorties could be conducted without weather interruption or disruption. The entire range is possible.

Title: **Mission Capable Rate of Force Mix**

Description: Extent to which aircraft in a candidate force mix are operationally capable of performing aerospace missions as designated by the theater or component commander.

Range of Measurement: 0 – 100 percent average mission capable rate. At 100 percent mission capability, all of the aircraft in the candidate force mix have 100 percent mission capable rates. At 0 percent mission capable, none of the aircraft within the force mix are mission capable. Both extremes are near-theoretical, short of pre-deployment generation or the grounding of a fleet for one time inspection or time compliance technical order. At 50 percent mission capable, some aircraft within the force mix could be higher while some are lower. All values within the range are possible.

Title: **Inter-mission Flexibility**

Description: Extent to which individual aircraft types within a candidate force mix can perform all of the aerospace missions defined in AFM 1-1 and AFDD 2-1. The relative worth of the force mix would be highest if it could perform all of the missions required by the theater or component commander [Buzo, 2000: 110].

Range of Measurement: capability to perform 0 – 100 percent of required missions. This is inter-mission flexibility. Therefore, at 0 percent, the force mix can perform one, but only one, type of aerospace mission. At 100 percent, the force mix can perform all of the potentially-desired aerospace missions as dictated by the theater or component commander. It is important to note that the force mix—as a collection of aircraft designs—can perform all of the missions. No single aircraft within the mix need be capable of such flexibility. All of the values within the range are possible.

Title: **Utilization Rate of Force Mix**

Description: Extent to which aircraft within the force mix are to be used in the performance of primary missions. This does not preclude *show of force* deployments.

Range of Measurement: 0 – 100 percent utilization rate. At 0 percent utilization rate, none of the aircraft within the force mix are to be used during the contingency. This would be an example of a *show of force* deployment. As utilization rates approach 100 percent, degradation of mission capability is highly probable. Therefore, this measure is monotonically decreasing. The higher the utilization rate, the lower the value to the decision maker. All of the values within the 0 – 100 percent range are possible.

Title: **USAF versus Enemy Capability**

Description: The comparison of enemy assets to USAF combat aircraft assets as contained in the candidate force mix. Assuming US forces' intelligence can discern the extent of the enemy's capability, this measure shows the relative worth of the amount of aircraft assets sent to the operating location. One issue addressed within the function is the number of USAF combat aircraft sent. The second issue is the capabilities of the enemy to counter the USAF force mix [Buzo, 2000: 111].

Range of Measurement: 0:1 to 3:1, ratio of USAF to enemy forces. As the ratio approaches 0:1, USAF forces are severely outmanned. At 1:1, USAF forces are equally offset by enemy forces. And as the ratio approaches 3:1, USAF forces gain a decided advantage. The entire range of ratios is possible, but as the USAF advantage passes 3:1, no additional value is attained and scarcity of resources reserved for other engagements becomes an issue.

Title: **Enemy Intelligence, Surveillance, and Reconnaissance (ISR) Impact**

Description: Addresses the enemy's ability to see or obtain information on US activity at the operating location. Enemy ISR could be obtained through aerial or satellite photography, local sympathizers monitoring US activity, or spies within the host nation working within or around the operating location [Buzo, 2000: 112]. Also necessarily addressed by this factor is the sensitivity to ISR of certain aircraft types within candidate force mixes, and the tradeoffs of such sensitivity with the enemy's ISR capabilities at the candidate operating location.

Range of Measurement: 0 – 100 percent degradation of mission due to enemy ISR. This is not a measure of exposure, but rather a measure of the negative impact of such exposure. At 0 percent mission degradation, all USAF combat sorties are conducted as scheduled and no sensitive assets are compromised. At 100 percent degradation, no sorties can go as scheduled due to enemy ISR and/or major, crippling information or intelligence has been surrendered to the enemy. All of the values within the range are possible.

Title: **Enemy Interference**

Description: Addresses the enemy's ability to interfere with US operations at the operating location. Interference is any action on the part of the enemy that could hamper US combat operations. The interference could range from relatively harmless demonstrations and propaganda to bomb threats and actual sabotage upon USAF assets and harm to personnel. This necessarily includes defensibility of the operating location from all-out attack upon the base, considering the strength of opposing forces in the vicinity of the operating location as well as the projected defense forces in place and/or to be sent.

Range of Measurement: 0 – 100 percent degradation of mission. At 0 percent degradation of mission, no enemy interference of any kind is to be encountered at the candidate operating location. At 100 percent degradation, enemy interference will halt all combat aerospace operations at the candidate operating location. The entire range of values within enemy interference is possible.

Appendix E: Rank-Ordering Sheets (Delphi Round 1)

THE ISSUE AND ITS MEASUREMENT	YOUR RANK
Multi-National Compatibility:... Compatibility between in-place host nation and US assets (0-100%)	
Beddown Location—Fighter Distance (refueled):........................... Deployed location's distance from enemy targets (0-3000 miles)	
Beddown Location—Bomber Distance (refueled):.......................... Deployed location's distance from enemy targets (0-7000 miles)	
Ability to Resupply:.. Ratio of consumption to resupply (0 to 1)	
Allow Assets In:.. Yes or No constraint	
International Politcs:.. Yes or No constraint	
Intra-National Politics:... Yes or No constraint	
Inter-Service Politics:... Yes or No constraint	
Intra-Service Politics:... Yes or No constraint	
Operating Location—Runway Length and Width:........................... Yes or No constraint	
Operating Location—Runway/Ramp Weight Capacity:..................... Yes or No constraint	
Operating Location—Ramp Space:.. Yes or No constraint	
Munitions Storage Area—Fighter:.. Percent of fighter sorties supportable per day (0-100%)	

THE ISSUE AND ITS MEASUREMENT YOUR RANK

Munitions Storage Area—Bomber:..
Percent of bomber sorties supportable per day (0-100%)

Petroleum, Oil, Lubricants (POL) Storage/Delivery:......................
Percent of force mix sorties supportable per day (0-100%)

Tanker Support Available:..
Percent of force mix sorties supportable per day (0-100%)

Operating Location—Topography:...
Percent degradation of Mission (0-100%)

Operating Location—Climate:...
Percent degradation of Mission (0-100%)

Asset Inter-Mission Flexibility:..
Percent of the required aerospace missions force mix is capable (0-100%)

Force Mix Utilization:..
Average expected utility of all aircraft in force mix (0-100%)

Availability of Force Mix:..
Average mission capable rate of aircraft in force mix (0-100%)

Enemy vs. USAF capability:...
Ratio of enemy-to-allied forces (0:1 to 3:1)

Enemy Intelligence, Surveillance, Reconnaissance (ISR) Impact:.........
Negative sortie impact of operations exposure to enemy (0-100%)

Enemy Interference:..
Percent degradation of mission (0-100%)

Is Force Mix Available to Deploy?..
Yes or No Constraint

Appendix F: Instructional Paper on Issue Weighting

1. The purpose of the upcoming research questionnaire is to obtain opinions and knowledge on the relative weightings between the campaign specific issues identified during previous interviews and research. The purpose of this background paper is to provide an understanding of the process of *swing weighting* and to present an example of such.

- Previous rounds of this study have determined relative ranking of Campaign Specific issues

  -- Ranking, based on level of importance, of issues has been determined

- The actual questionnaire will consist of comparing 15 *sets* of two separate campaign specific issues to determine relative weights of all issues

2. To understanding how comparisons will be conducted, an example is provided. When deciding to purchase a car, many features must be considered. Consider two cars; Car 'A' has all 3 of the safety features required (i.e. anti-lock brakes, traction control, and dual air bags), and costs $25,000. Car 'B' has 1 of the 3 safety features (dual air bags) needed, and costs $20,000. For simplicity, other features will be disregarded.

- First, the value of these issues (safety features available and cost) based upon personal requirements must be identified.

  -- Determine 'value' for the price of the car, based on personal requirements

    --- Paying $20,000 or less is optimal, resulting in a value of 1.0 at $20,000

    --- Paying $30,000 or more is bad, resulting in a value of 0 at $30,000

    --- Value decreases linearly between $20,000 and $30,000 ($25,000 results in a value of 0.5)

-- Determine 'value' for having safety features, based on personal requirements

--- Having all 3 safety features is optimal, resulting in a value of 1.0 for all three

--- Having none of the safety features is very bad, resulting in a value of 0.

--- Value decreases equally between 3 to no features (1 feature results in a value of 0.33, 2 features result in a value of 0.66)

-- Using the example, 'Safety' value of Car 'A' is 1.0, and 'Cost' value is 0.5

-- 'Safety' value of Car 'B' is 0.33, 'Cost' value is 1.0

- Next, relative weighting between two issues must be determined

-- It is determined that safety features are more important than cost

-- Compare 'range of measurement' of safety (0 to 3 features) to 'range of measurement' of cost ($20,000 to $30,000)

--- As safety features more important than cost, compare cost to safety by asking the following question:

WHAT PORTION OF THE 'RANGE OF MEASUREMENT' OF SAFETY *EQUALS* THE 'RANGE OF MEASUREMENT' OF COST?

--- Question determines level of concern over reduced value between two issues

--- If cost *swings* from $20,000 to $30,000 (best value to worst value), what would be the equivalent loss in safety features.

--- Based on personal belief, it is determined a *swing* in cost from $20,000 to $30,000 (best value to worst value) is comparable (same level of unhappiness is felt) to a *swing* in losing 1 safety feature (going from 3 to 2 safety features)

-- Although we will not be discussing this in the interview, value analysis of the two choices continues with converting range of measurement to value.

-- It is determined that Safety features are 3 times as important as cost (1 times the entire range of cost = 1/3 entire range of safety)

-- Combining both issues to compare different cars, individual weights must sum to 1

“cost’ + ‘safety’ = 1

3 x ‘Cost’ = ‘Safety’

Combining two equations, ‘Cost’ + (3 x ‘Cost’) = 1, Therefore Cost = 0.25

-- Weight of ‘Cost’ is 0.25 and weight of ‘Safety’ is 0.75.

- Once values and relative weightings identified for two issues, individual cars can be compared to determine ‘best value’ car for the buyer

-- Comparison of different cars based upon summing the following to determine total value:

Value of ‘Cost’ x Weight of ‘Cost’
Value of ‘Safety’ x Weight of ‘Safety’

-- Using example, Car ‘A’ commands total value of:
(0.5 x 0.25) + (1 x 0.75) = 0.88

-- Car ‘B’ commands total value of:
(1.0 x 0.25) + (0.33 x 0.75) = 0.50

-- Therefore, based on value analysis, choose Car ‘A’ as car with highest total value

3. Over the course of this research, the ranges of measurement for each individual Campaign Specific Issue has been determined. The relative importance ranking of the Campaign Specific Issues have also been identified. The purpose of the interview is to obtain the relative weightings for these issues in the manner discussed in this paper.

4. Thank you very much for your time and support of this research effort. If you have any questions about the method in which the interview will be conducted or for any other reason, please do not hesitate to e-mail me at **Paul.filcek@afit.af.mil**.

1Lt Paul Filcek/AFIT/ENS/(937)254-5895/12Jan01

Appendix G: Delphi Rounds 2 and 3 Questionnaire

Please answer all questions on this document and return within an e-mail to: Paul.Filcek@afit.af.mil

The Purpose of this questionnaire is to determine relative weightings: between the *sub-issues* within a parent issue (i.e. Multi-National Compatibility, Allow Assets In, etc. within Host Nation); and between *parent issues* (i.e. Host Nation, Enemy, etc)

During previous questionnaires, the relative rankings of importance between the campaign specific issues have been determined. Based upon these results, issues recognized to be more potentially influential will be ranked against those issues not as potentially influential to the selection of combat aircraft to deploy in response to a contingency crisis.

Please compare the Campaign Specific Issue in 'Column A' to the Campaign Specific Issue in 'Column B'. In each case, the issue in 'Column A' has been identified to be more potentially important than the issue in 'Column B'. Looking at the range of measurement for each issue, PLEASE STATE HOW MANY TIMES MORE IMPORTANT THE SWING FROM BEST SCORE TO WORST SCORE FOR THE ISSUE IN COLUMN 'A' IS THAN THE SWING FROM BEST SCORE TO WORST SCORE FOR THE ISSUE IN COLUMN 'B'.

Consider this example. Compare Petroleum, Oil and Lubricants (POL) to Beddown Location: Fighter Distance. The swing from best to worst score for POL is 100 percent to 0 percent support of asset sorties per day. The swing from best to worst score for Beddown Location: Fighter Distance is 0mi to 3000mi distance from the pre-determined staging base to the enemy target. I believe that, if POL were to drop from 100 percent to 0 percent, this drop would be 4 times worse than if Beddown Location: Fighter Distance were to increase from 0 mi to 3000 mi from the enemy target. As my answer, I put 4 in the middle block.

COLUMN A	IS HOW TIMES MORE IMPORTANT THAN	COLUMN B
Petroleum, Oil, Lubricants (100% to 0% asset sets supported per day)	4	Beddown Location: Fighter Distance (0-3000mi distance to enemy target)

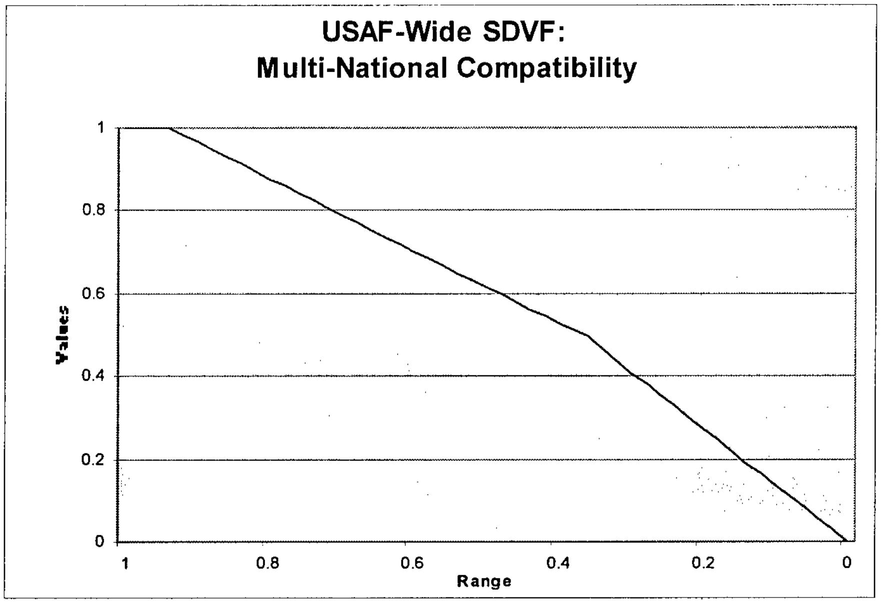
Based upon this **example**, please provide your answer to the following comparisons. If you feel that the issue in 'Column A' is less important than the issue in 'Column B', <u>please use fractions</u> (1/2, 1/3, etc.).

QUESTIONNAIRE ANSWER SHEET

COLUMN A	IS HOW MANY TIMES MORE IMPORTANT THAN	COLUMN B
Petroleum, Oil, Lubricants (100% to 0% assets supported/day)		Beddown Location: Fighter Distance (0mi to 3000mi distance to enemy)
Enemy Vs. USAF Capability (3 to 0 USAF to Enemy Ratio)		Petroleum, Oil, Lubricants (100% to 0% asset sets supported/day)
Enemy Vs. USAF Capability (3 to 0 USAF to Enemy Ratio)		Mission Capable Rate of Assets (100% to 0% average MC rate of acft)
Mission Capable Rate of Assets (100% to 0% avg MC rate of acft)		Multi-National Compatibility (100%-0% compatibility w/ host)
Beddown Location: Fighter Distance (0-3000mi distance to enemy targets)		Beddown Location: Bomber Distance (0-7000mi distance to enemy target)
Beddown Location: Fighter Distance (0-3000mi distance to enemy target)		Ability to Resupply (1 to 0 ratio: consumption to resupply)
Petroleum, Oil, Lubricants (100% to 0% assets supported/day)		Munitions Storage Area: Fighter (100-0% fighter sorties supported/day)
Petroleum, Oil, Lubricants (100% to 0% assets supported/day)		Munitions Storage Area: Bomber (100-0% bomber sorties supported/day)
Petroleum, Oil, Lubricants (100% to 0% assets supported/day)		Tanker Support Required (0-100% sorties supported/day)
Topography (100% to 0% mission degradation)		Climate (100% to 0% mission degradation)
Mission Capable Rate of Assets (100%-0% average MC rate of acft)		Asset Mission Flexibility (100-0% capability of all aerospace missions)
Mission Capable Rate of Assets (100%-0% average MC rate of acft)		Asset Set Utilization (0-100% utility of all aircraft in set)
Enemy Vs. USAF Capability (3 to 0 USAF to Enemy Ratio)		Enemy Surveillance, Intel, and Recon (0-100% impact of exposure to enemy)
Enemy Vs. USAF Capability (3 to 0 USAF to Enemy Ratio)		Enemy Interference (0% to 100% mission degradation)
Topography (100% to 0% mission degradation)		Beddown Location: Fighter Distance (0mi to 3000mi distance to enemy)

Thank you very much for your support of this research. I greatly appreciate the time you took to complete these questionnaires. I will be concluding this study with a conclusion questionnaire in which I will present a summary of these individual Campaign Specific Issue weights, as determined by the expert group. You will have an opportunity to revise or defend you're your weightings in this final questionnaire. THANK YOU VERY MUCH!

Appendix H: USAF-Wide Single-Dimension Value Functions



Computed from the following *individual* single-dimension value functions:

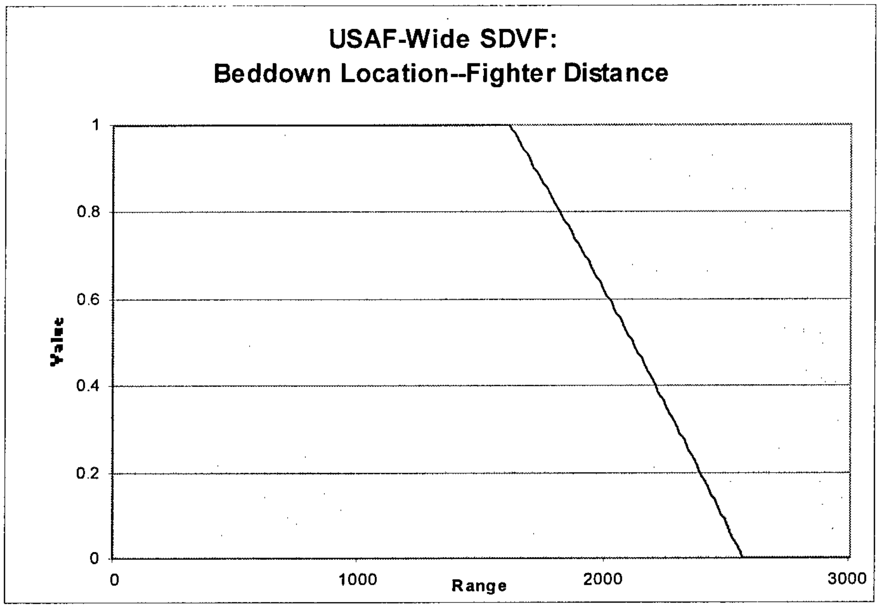
CentAF SDVF			
Percent Compatible	Score		
1	1		
0.4	0.5	Rho	-25.00
0	0	Rho	15.00

SouthAF SDVF			
Percent Compatible	Score		
1	1		
0.4	0.5	Rho	-25.00
0	0	Rho	15.00

AEFC SDVF			
Percent Compatible	Score		
1	1		
0.38	0.5	Rho	-13.02
0	0	Rho	21.28

CADRE SDVF			
Percent Compatible	Score		
1	1		
0.84	1		
0.35	0.5	Rho	-875
0	0	Rho	-875

ACC SDVF			
Percent Compatible	Score		
1	1		
0.43	0.5	Rho	-79.80
0	0	Rho	-60.20



Computed from the following *individual* single-dimension value functions:

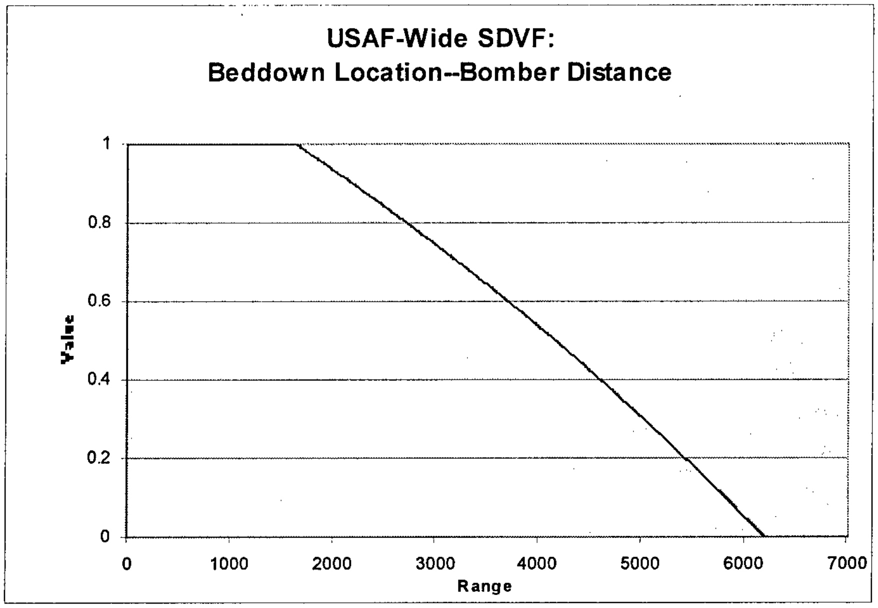
CentAF SDVF			
Miles from Targets	Score		
0	1		
2	1		
2.5	0	Rho	-0.10

SouthAF SDVF			
Miles from Targets	Score		
0	1		
1	1		
2.5	0	Rho	1000

AEFC SDVF			
Miles from Targets	Score		
0	1		
1.6	1		
2.6	0	Rho	0.60

CADRE SDVF			
Miles from Targets	Score		
0	1		
2.15	1		
2.65	0	Rho	-0.28

ACC SDVF			
Miles from Targets	Score		
0	1		
1.3	1		
2.6	0	Rho	1.30



Computed from the following *individual* single-dimension value functions:

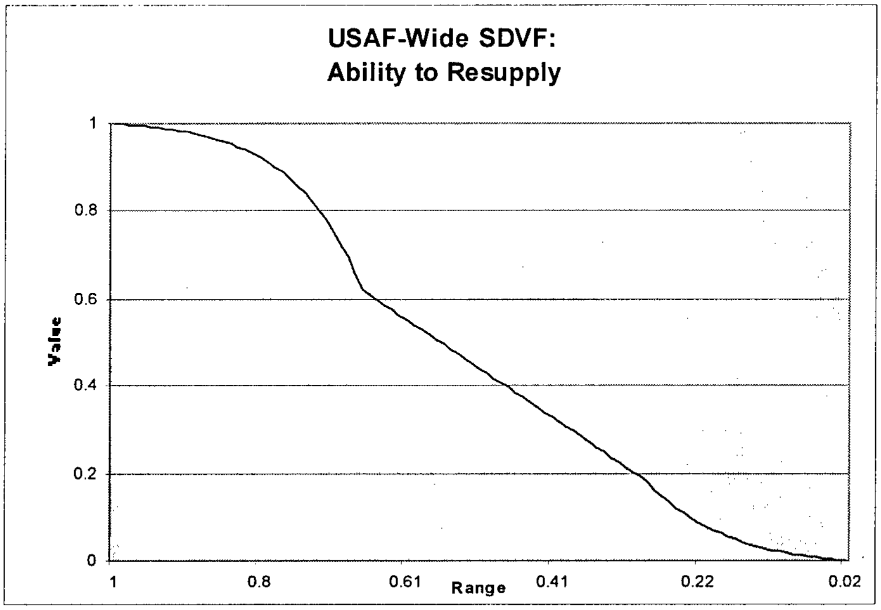
CentAF SDVF			
Miles from Targets	Score		
0	1		
2	1		
6.5	0	Rho	9.95

SouthAF SDVF			
Miles from Targets	Score		
0	1		
1.5	1		
6	0	Rho	2.07

AEFC SDVF			
Miles from Targets	Score		
0	1		
2	1		
6.5	0	Rho	-3.15

CADRE SDVF			
Miles from Targets	Score		
0	1		
1.65	1		
6.25	0	Rho	2.58

ACC SDVF			
Miles from Targets	Score		
0	1		
1	1		
5.75	0	Rho	-11.88



Computed from the following *individual* single-dimension value functions:

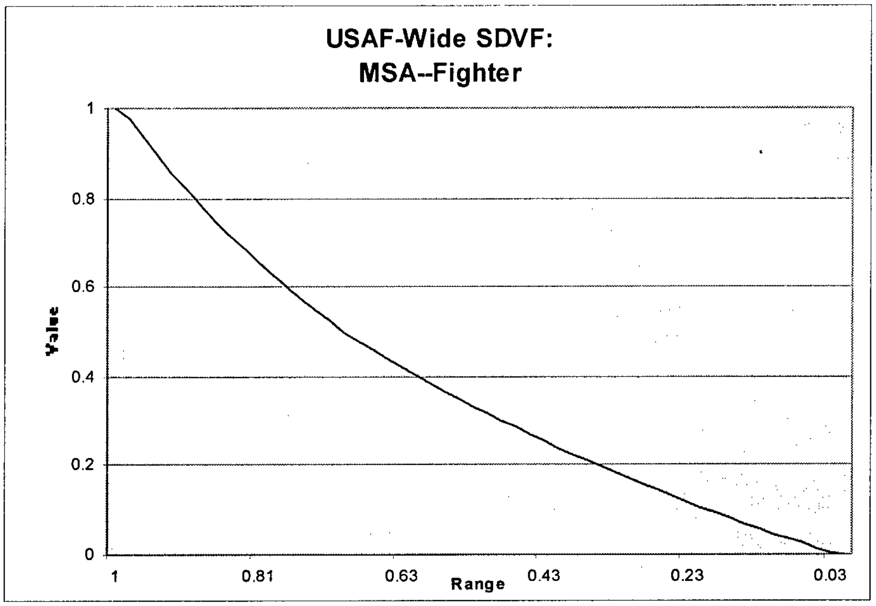
CentAF SDVF			
Ratio: Supply to Consumption	Score		
0	0		
0.2	0.15	Rho	0.10
0.6	0.85		
1	1	Rho	-0.10

SouthAF SDVF			
Ratio: Supply to Consumption	Score		
0	0		
0.15	0.15	Rho	150
0.6	0.7		
1	1	Rho	-0.164

AEFC SDVF			
Ratio: Supply to Consumption	Score		
0	0		
0.65	0.4	Rho	0.31
1	1	Rho	-0.18

CADRE SDVF			
Ratio: Supply to Consumption	Score		
0	0		
0.35	0.2	Rho	0.042
0.45	0.55		
1	1	Rho	-0.0715

ACC SDVF			
Ratio: Supply to Consumption	Score		
0	0		
0.5	0.5	Rho	500
1	1	Rho	500



Computed from the following *individual* single-dimension value functions:

CentAF SDVF

Percent sorties / day	Score		
0	0		
1	1	Rho	-0.31

SouthAF SDVF

Percent sorties / day	Score		
0	0		
1	1	Rho	-0.41

AEFC SDVF

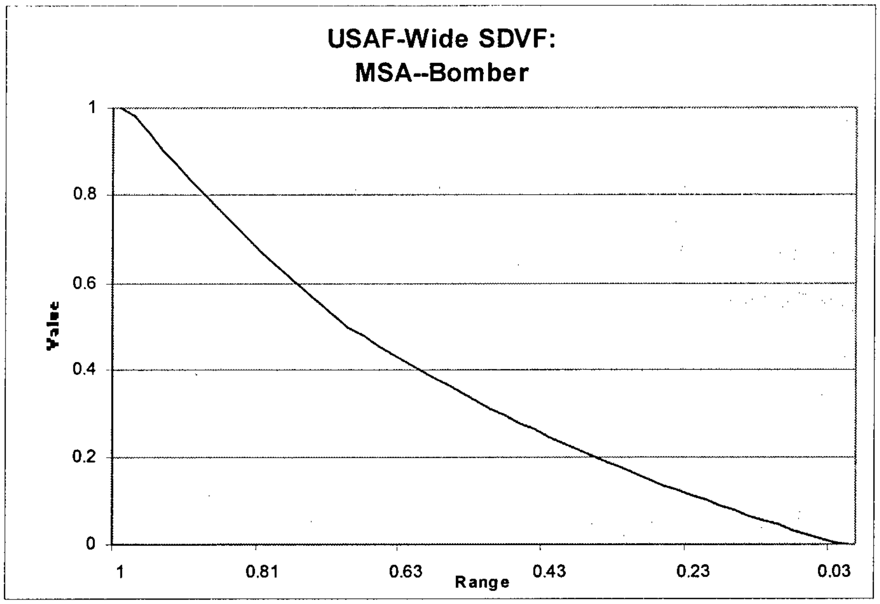
Percent sorties / day	Score		
0	0		
1	1	Rho	1000

CADRE SDVF

Percent sorties / day	Score		
0	0		
0.65	0.5	Rho	-0.1495
1	1	Rho	0.26

ACC SDVF

Percent sorties / day	Score		
0	0		
1	1	Rho	-0.56



Computed from the following *individual* single-dimension value functions:

CentAF SDVF

Percent sorties / day	Score		
0	0		
1	1	Rho	-0.31

SouthAF SDVF

Percent sorties / day	Score		
0	0		
1	1	Rho	-0.41

AEFC SDVF

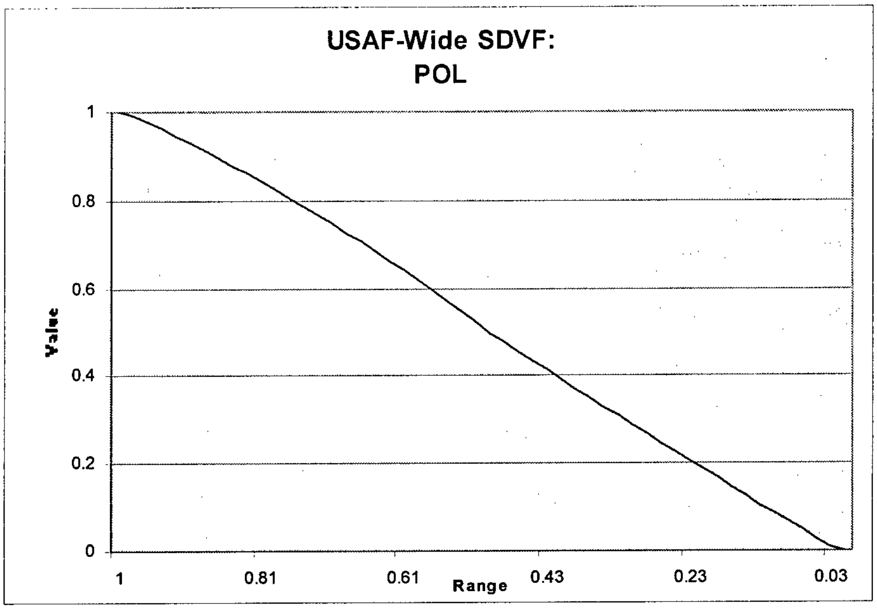
Percent sorties / day	Score		
0	0		
1	1	Rho	1000

CADRE SDVF

Percent sorties / day	Score		
0	0		
0.68	0.5	Rho	-0.2584
1	1	Rho	0.28

ACC SDVF

Percent sorties / day	Score		
0	0		
1	1	Rho	-0.56



Computed from the following *individual* single-dimension value functions:

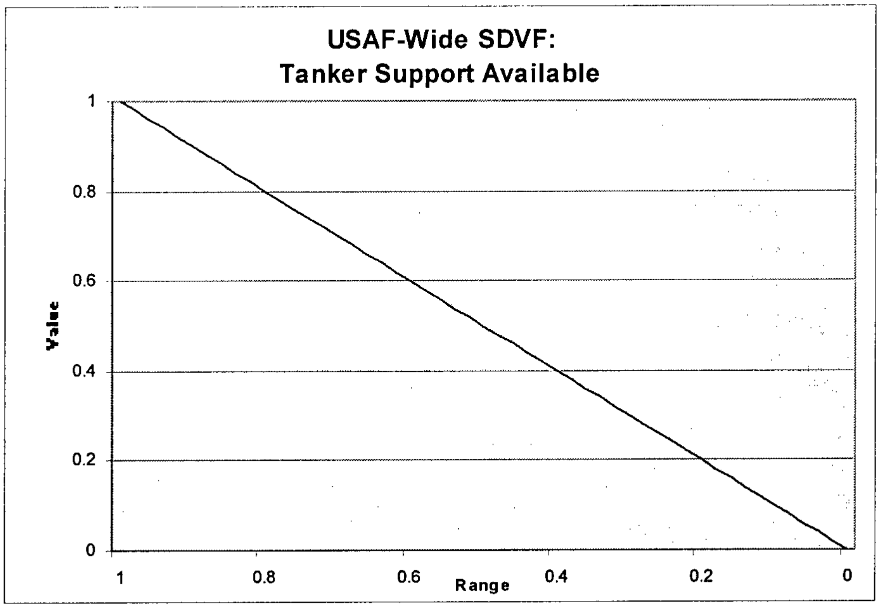
CentAF SDVF			
Percent sorties / day	Score		
0	0		
1	1	Rho	1000

SouthAF SDVF			
Percent sorties / day	Score		
0	0		
1	1	Rho	1000

AEFC SDVF			
Percent sorties / day	Score		
0	0		
1	1	Rho	1000

CADRE SDVF			
Percent sorties / day	Score		
0	0		
0.45	0.5	Rho	-0.5472
1	1	Rho	0.19

ACC SDVF			
Percent sorties / day	Score		
0	0		
1	1	Rho	1000



Computed from the following *individual* single-dimension value functions:

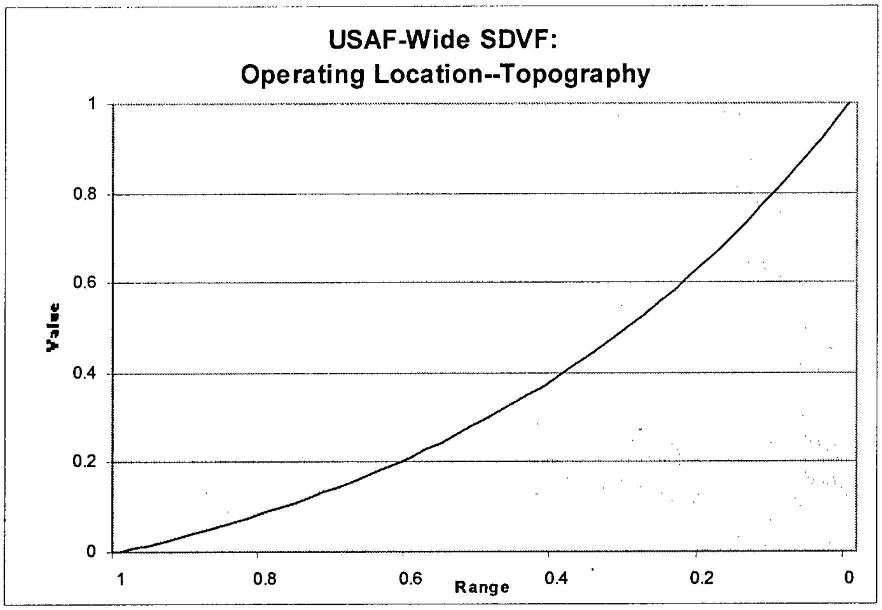
CentAF SDVF			
Pct Missions supported/day	Score		
0	0		
1	1	Rho	1000

SouthAF SDVF			
Pct Missions supported/day	Score		
0	0		
1	1	Rho	1000

AEFC SDVF			
Pct Missions supported/day	Score		
0	0		
1	1	Rho	1000

CADRE SDVF			
Pct Missions supported/day	Score		
0	0		
1	1	Rho	1000

ACC SDVF			
Pct Missions supported/day	Score		
0	0		
1	1	Rho	1000



Computed from the following *individual* single-dimension value functions:

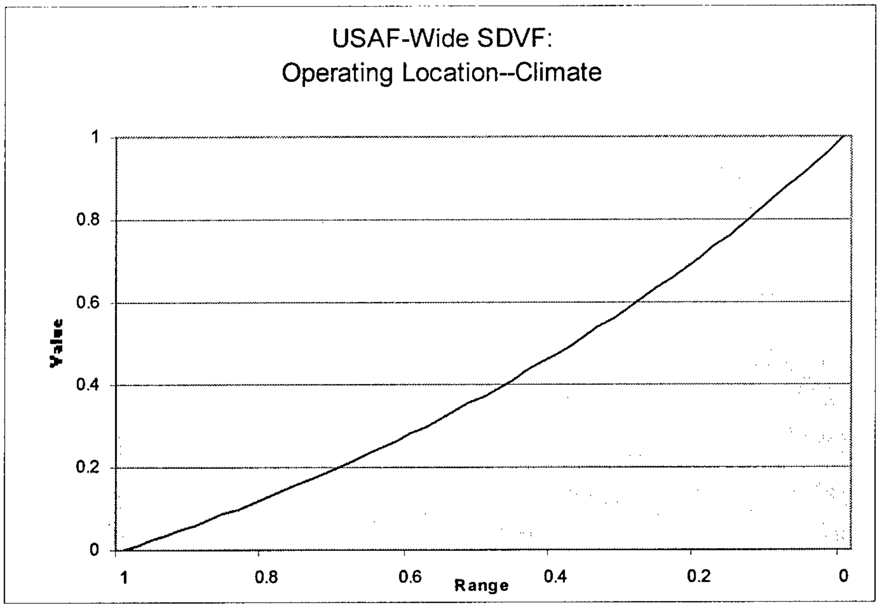
CentAF SDVF			
Topography Difficulties	Score		
0	1		
1	0	Rho	-0.27

SouthAF SDVF			
Topography Difficulties	Score		
0	1		
1	0	Rho	-0.20

AEFC SDVF			
Topography Difficulties	Score		
0	1		
1	0	Rho	1000

CADRE SDVF			
Topography Difficulties	Score		
0	1		
1	0	Rho	1.216

ACC SDVF			
Topography Difficulties	Score		
0	1		
1	0	Rho	-0.14



Computed from the following *individual* single-dimension value functions:

CentAF SDVF

Climate Difficulties	Score		
0	1		
1	0	Rho	-0.27

SouthAF SDVF

Climate Difficulties	Score		
0	1		
1	0	Rho	1000

AEFC SDVF

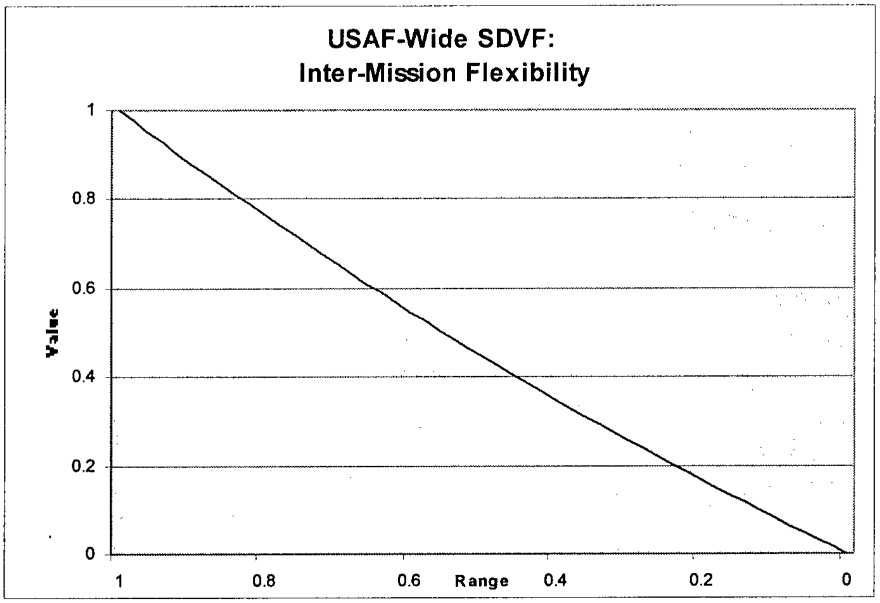
Climate Difficulties	Score		
0	1		
1	0	Rho	1000

CADRE SDVF

Climate Difficulties	Score		
0	1		
1	0	Rho	1.216

ACC SDVF

Climate Difficulties	Score		
0	1		
1	0	Rho	-0.14



Computed from the following *individual* single-dimension value functions:

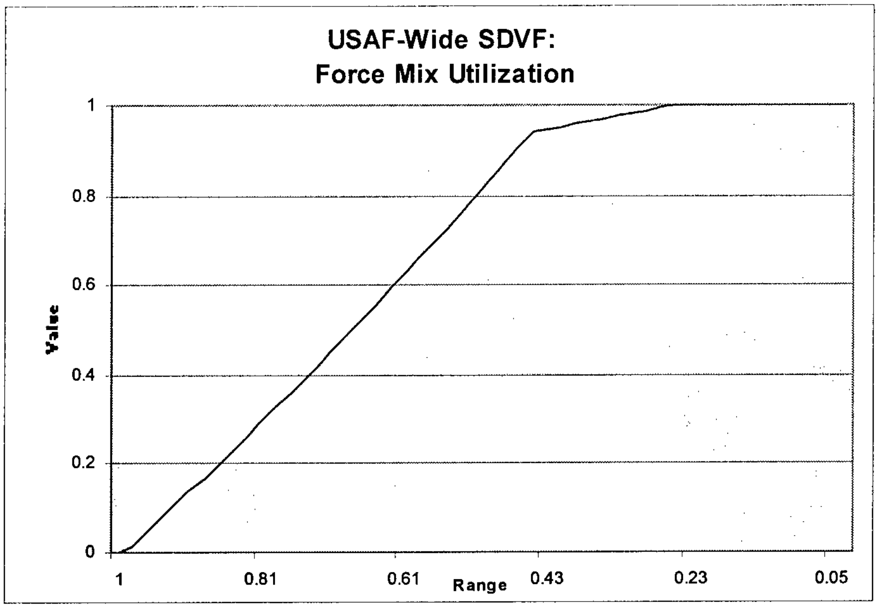
CentAF SDVF			
Pct Mission Interchamgeable	Score		
0	0		
1	1	Rho	1000

SouthAF SDVF			
Pct Mission Interchamgeable	Score		
0	0		
1	1	Rho	-0.39

AEFC SDVF			
Pct Mission Interchamgeable	Score		
0	0		
1	1	Rho	1000

CADRE SDVF			
Pct Mission Interchamgeable	Score		
0	0		
1	1	Rho	1000

ACC SDVF			
Pct Mission Interchamgeable	Score		
0	0		
1	1	Rho	1000



Computed from the following *individual* single-dimension value functions:

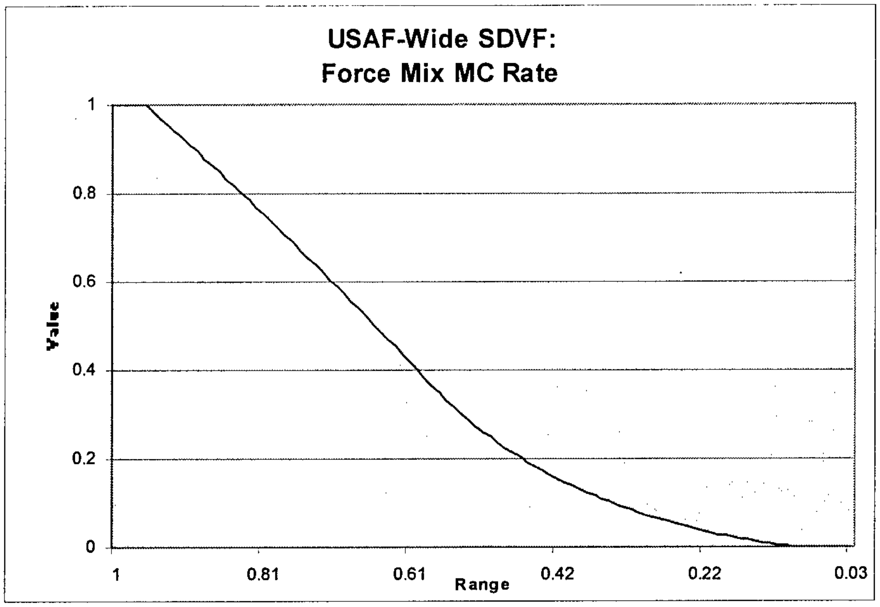
CentAF SDVF			
Average Utilization	Score		
0	1		
0.7	0.98		
1	0	Rho	-0.2076

SouthAF SDVF			
Average Utilization	Score		
0	1		
0.5	1		
1	0	Rho	0.2775

CADRE SDVF			
Average Utilization	Score		
0	1		
0.54	0.66	Rho	0.101
0.72	0.23		
1	0	Rho	-0.2324

AEFC SDVF			
Average Utilization	Score		
0	1		
0.3	1		
0.65	0.8	Rho	0.26
0.75	0.25		
1	1	Rho	-0.2113

ACC SDVF			
Average Utilization	Score		
0	1		
0.35	1		
1	0	Rho	0.38



Computed from the following *individual* single-dimension value functions:

CentAF SDVF

MC Rate	Score		
0	0		
0.3	0		
0.7	0.5	Rho	-0.1
1	1	Rho	0.15

SouthAF SDVF

MC Rate	Score		
0	0		
0.1	0		
0.5	0.2	Rho	-0.3648
0.76	0.8		
1	1	Rho	0.3162

AEFC SDVF

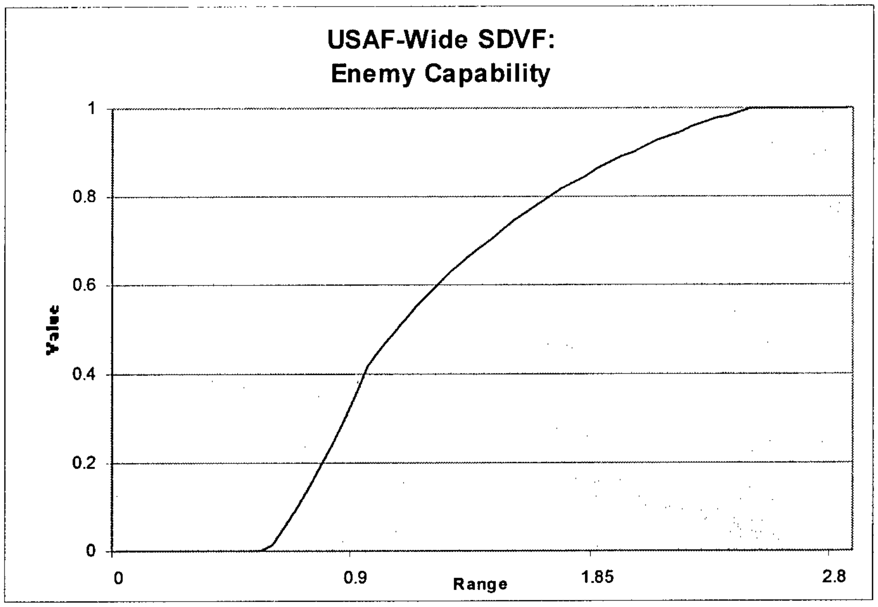
MC Rate	Score		
0	0		
0.9	1	Rho	-0.32
1	1		

CADRE SDVF

MC Rate	Score		
0	0		
1	1	Rho	-2.063

ACC SDVF

MC Rate	Score		
0	0		
0.64	0.48	Rho	-0.22
0.8	0.9	Rho	0.15
1	1		



Computed from the following *individual* single-dimension value functions:

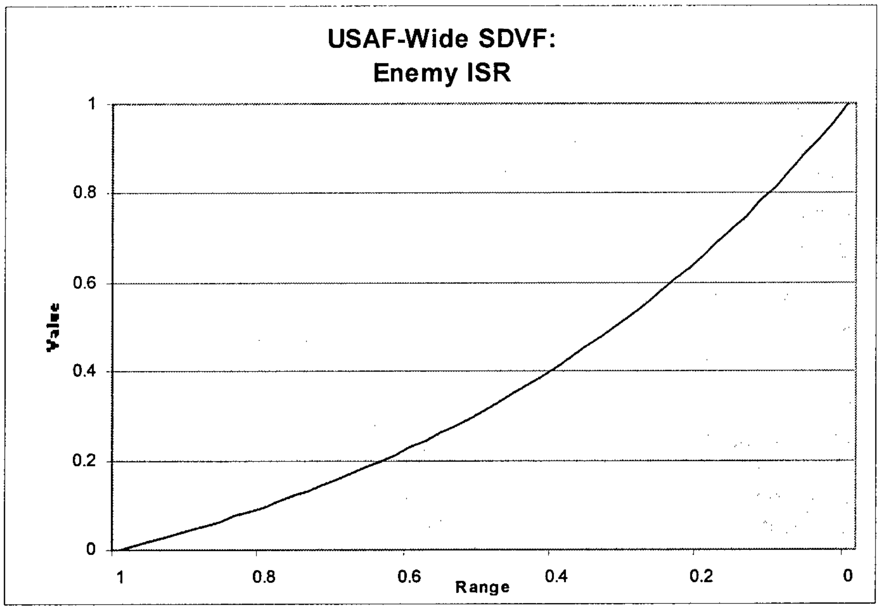
CentAF SDVF			
Ratio: USAF to enemy	Score		
0	0		
0.8	0		
1	0.2	Rho	-0.03
1.5	0.5	Rho	-0.22
3	1	Rho	0.1554

SouthAF SDVF			
Ratio: USAF to enemy	Score		
0	0		
0.8	0		
2	1	Rho	0.492
3	1		

AEFC SDVF			
Ratio: USAF to enemy	Score		
0	0		
0.5	0		
1.6	0.8		
2	1	Rho	0.946
3	1		

CADRE SDVF		
Ratio: USAF to enemy	Score	
0	0	
0.8	0	
1	0.4	PL
2	0.8	PL
3	1	PL

ACC SDVF			
Ratio: USAF to enemy	Score		
0	0		
1	0.8	Rho	-0.41
3	1		



Computed from the following *individual* single-dimension value functions:

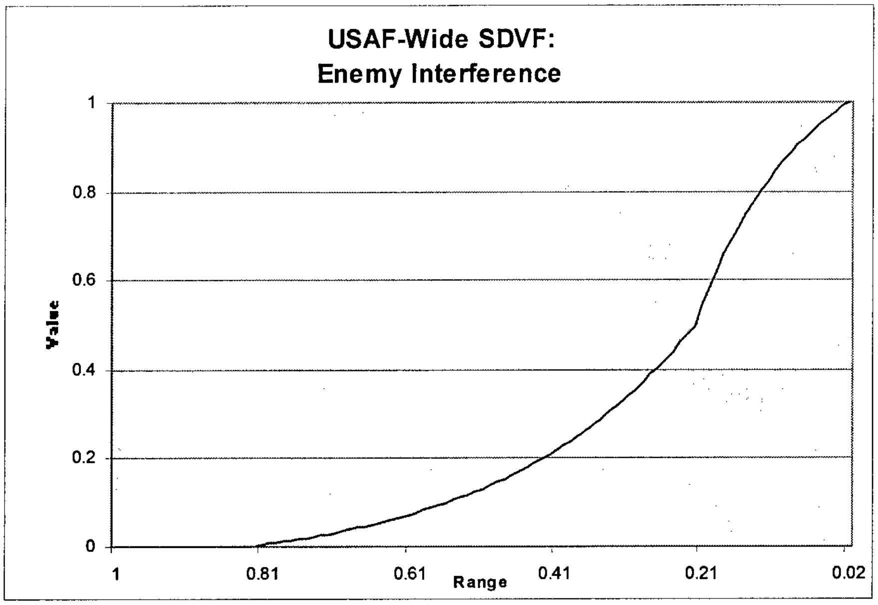
CentAF SDVF			
Pct Ops Exposure	Score		
0	1		
1	0	Rho	-0.41

SouthAF SDVF			
Pct Ops Exposure	Score		
0	1		
1	0	Rho	-0.66

AEFC SDVF			
Pct Ops Exposure	Score		
0	1		
1	0	Rho	-0.49

CADRE SDVF			
Pct Ops Exposure	Score		
0	1		
0.56	0.15	Rho	-0.253
1	0		

ACC SDVF			
Pct Ops Exposure	Score		
0	1		
1	0	Rho	1000



Computed from the following *individual* single-dimension value functions:

CentAF SDVF

Enemy Effect	Score		
0	1		
0.5	0	Rho	-0.15
1	0		

SouthAF SDVF

Enemy Effect	Score		
0	1		
1	0	Rho	-0.27

AEFC SDVF

Enemy Effect	Score		
0	1		
0.3	0.58	Rho	0.42
0.8	0	Rho	-0.36
1	0		

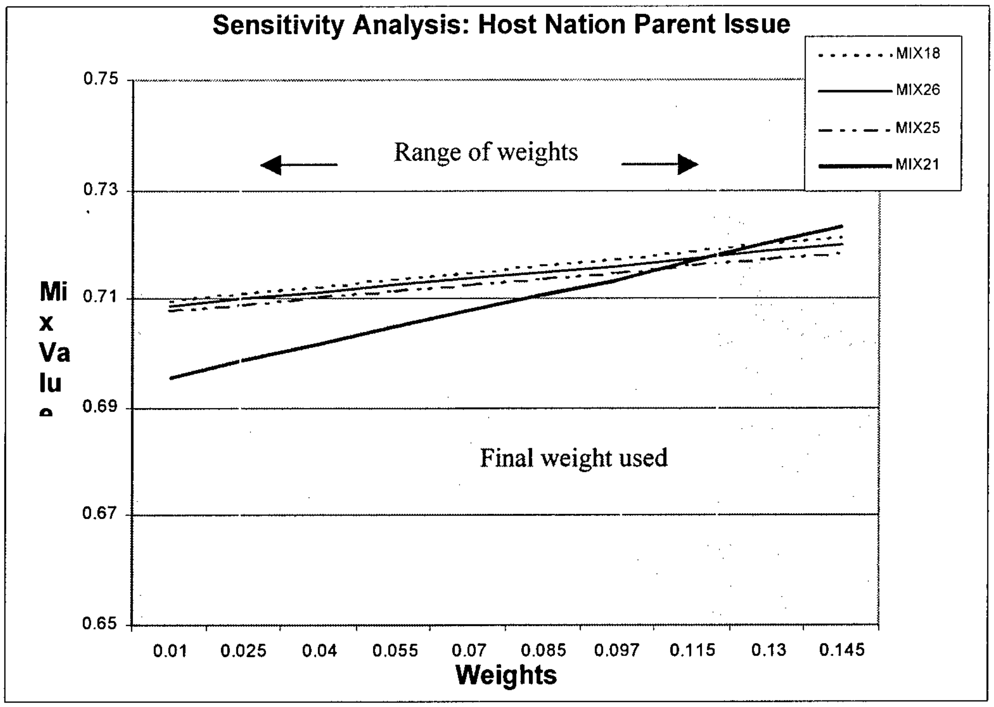
CADRE SDVF

Enemy Effect	Score		
0	1		
0.8	0	Rho	-0.176
1	0		

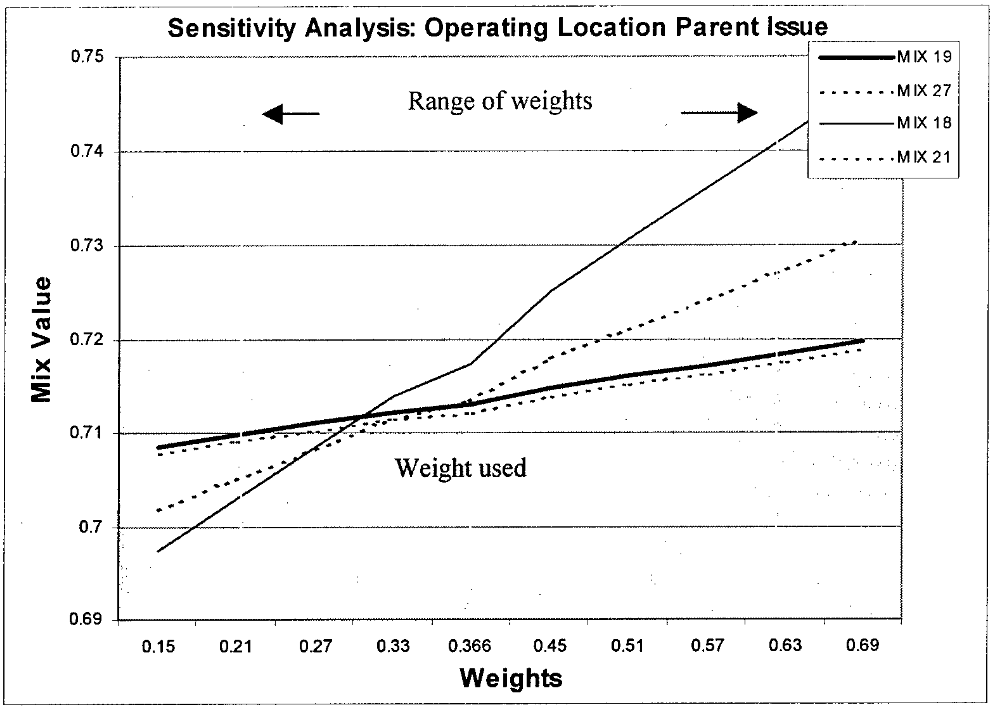
ACC SDVF

Enemy Effect	Score		
0	1		
0.36	0.5	Rho	0.07
1	0	Rho	-0.12

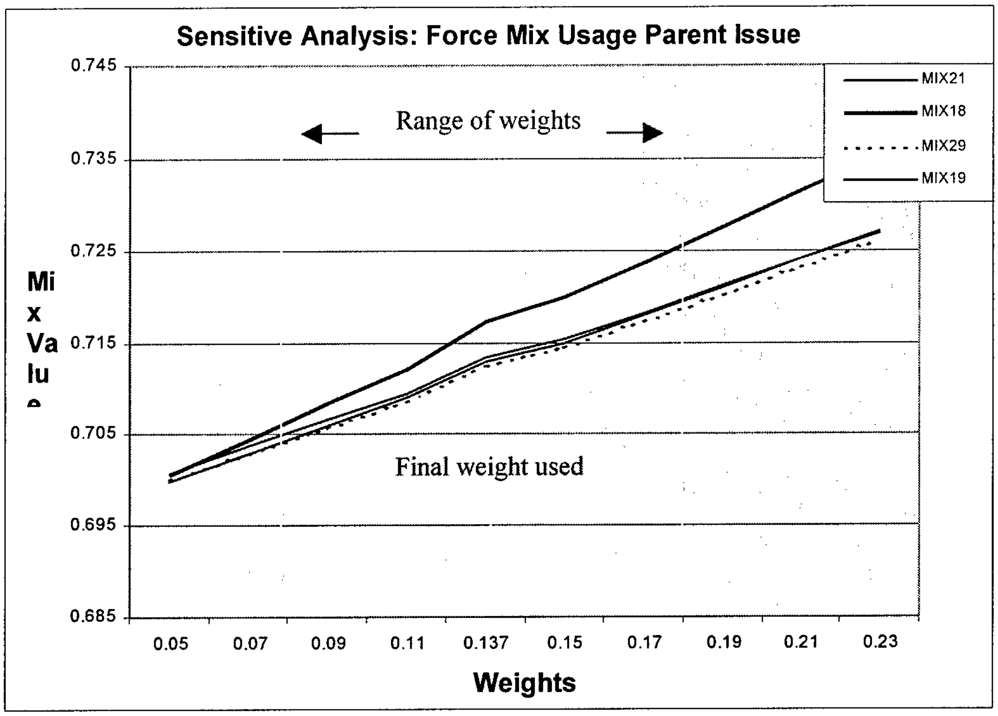
Appendix I: Sensitivity Analysis on Parent Issue Weights



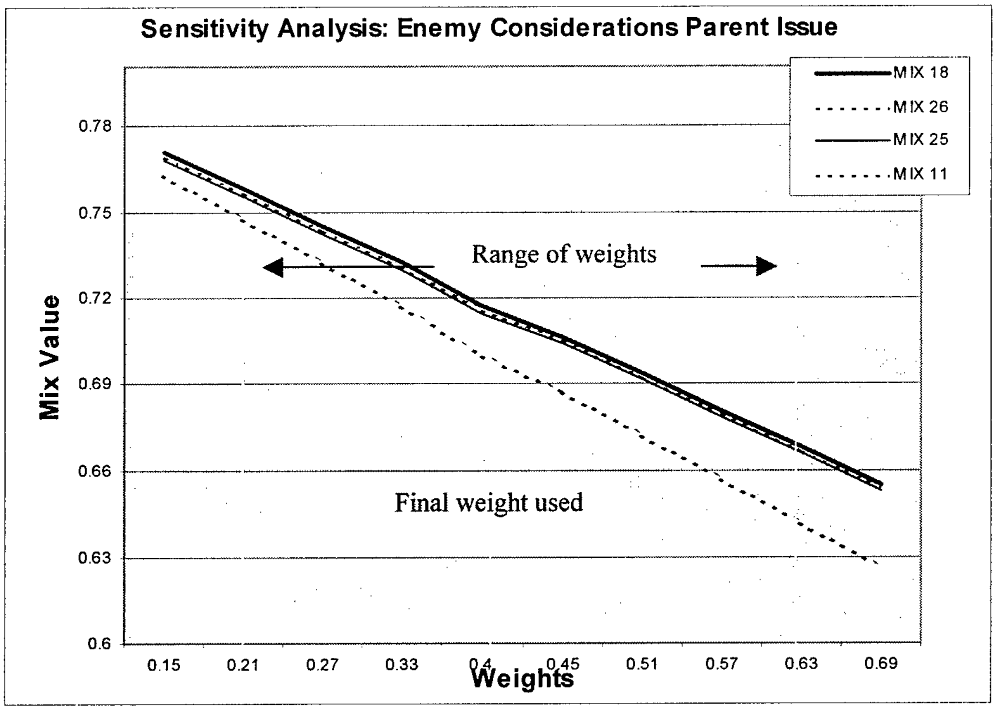
No change in the most favored force mix (#18) within the range of weights used.



Just *one change* in the most favored force mix, from #19 to #18, within the range of weights used. The actual change in rank occurred near the value of the final weight used, lending evidence as to the final weight's appropriateness.

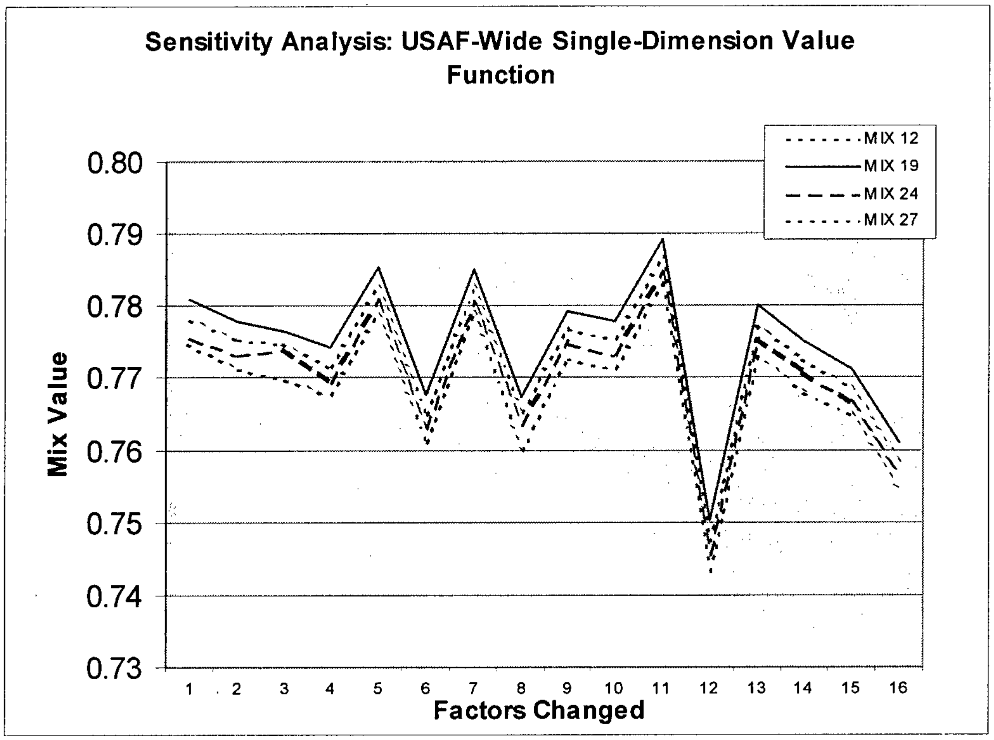


No change in the most favored force mix (#18) within the range of weights used.



No change in the most favored force mix (#18) within the range of weights used.

Appendix J: Sensitivity Analysis on the USAF-Wide SDVF's



Each of the 16 *USAF-wide* SDVF's was constructed from the 80 individual SDVF's elicited from AEFC, CentAF, ACC, CADRE, and SouthAF (five for each of 16 factors). The 16 USAF-wide SDVF's comprise the extrinsic force evaluation tool (*go/no go* filter notwithstanding).

The graph above represents the top four force mixes as scored using the USAF-wide SDVF's. However, each point along the X-axis has *one* of the 16 factors represented by the *most divergent individual SDVF* for that factor (i.e., AEFC for POL).

As can be seen, none of the top four force mixes change their relative ranking using a *single dissenting* SDVF. This provides evidence for the robustness of the USAF-wide SDVF's.

It is important to note that a small number of changes in rankings did occur among lower ranked force mixes. However, these changes were, in every case, among force mixes of almost identical assets. Among differentiated force mixes, no rank changes occurred.

Appendix K: Input Sheets for Scoring Force Mixes

The "*Go / No Go* Filter" (constraints) sheet, less the *Go / No Go* score column (included in actual sheet). The constraints are specific to the aircraft types *within* a candidate force mix, which then drive a force mix's initial feasibility. This sheet is linked by formulas to the "Scored Force Mixes" sheet. Manual inputs into either sheet affect the other.

			FA	FB	FC	B1	B2
Test 1	**POLITICS:** Force Mix Allowed?		1	1	1	1	1
		FLAG:					
Test 2	**OPERATING LOCATION:** Runway Length/Width		1	1	1	1	1
		FLAG:					
Test 3	**OPERATING LOCATION:** Runway Weight Capacity		1	1	1	1	1
		FLAG:					
Test 4	**OPERATING LOCATION:** Ramp Space		1	1	1	1	1
		FLAG:					F
Test 5	Desired Force Mix **AVAILABLE?**		1	1	1	1	1
	(reconstitution, rotations, fleet modifications, etc)	FLAG:			F		
Test 6	**NON-IFR DISTANCE:** <700mi/Fighter, 3000mi/Bomber		1	1	1	1	1
	(applies if no tankers available, distance can't exceed)	FLAG:					
**	F: A condition that must be accounted for in the constraint formula specific to the force						

Calc box for distance:

Tankers Available:	1
Miles from target/F:	0
Miles from target/B:	1

MIX	FA	FB	FC	B1	B2	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Passed
1	12	24	0	3	0	1	1	1	1	1	1	6
2	24	12	0	3	0	1	1	1	1	1	1	6
3	24	12	0	0	3	1	1	1	1	1	1	6
4	12	24	0	0	3	1	1	1	1	1	1	6
5	12	0	24	3	0	1	1	1	1	1	1	6
6	0	12	24	3	0	1	1	1	1	1	1	6
7	12	0	24	0	3	1	1	1	1	1	1	6
8	0	12	24	0	3	1	1	1	1	1	1	6
9	0	24	12	3	0	1	1	1	1	1	1	6
10	24	0	12	3	0	1	1	1	1	1	1	6
11	0	24	12	0	3	1	1	1	1	1	1	6
12	24	0	12	0	3	1	1	1	1	1	1	6
13	12	24	0	2	1	1	1	1	1	1	1	6
14	24	12	0	1	2	1	1	1	1	1	1	6
15	24	12	0	2	1	1	1	1	1	1	1	6
16	12	24	0	1	2	1	1	1	1	1	1	6
17	12	0	24	2	1	1	1	1	1	1	1	6
18	0	12	24	1	2	1	1	1	1	1	1	6
19	12	0	24	2	1	1	1	1	1	1	1	6
20	0	12	24	1	2	1	1	1	1	1	1	6
21	0	24	12	2	1	1	1	1	1	1	1	6
22	24	0	12	1	2	1	1	1	1	1	1	6
23	0	24	12	2	1	1	1	1	1	1	1	6
24	24	0	12	1	2	1	1	1	1	1	1	6
25	36	0	0	3	0	1	1	1	1	1	1	6
26	36	0	0	0	3	1	1	1	1	1	1	6
27	36	0	0	2	1	1	1	1	1	1	1	6
28	0	36	0	3	0	1	1	1	1	1	1	6
29	0	36	0	0	3	1	1	1	1	1	1	6
30	0	36	0	1	2	1	1	1	1	1	1	6
31	0	0	36	3	0	1	1	1	1	1	1	6
32	0	0	36	0	3	1	1	1	1	1	1	6
33	0	0	36	2	1	1	1	1	1	1	1	6
34	18	18	0	1	2	1	1	1	1	1	1	6
35	0	18	18	2	1	1	1	1	1	1	1	6
36	18	0	18	1	2	1	1	1	1	1	1	6
37	18	18	0	3	0	1	1	1	1	1	1	6
38	0	18	18	3	0	1	1	1	1	1	1	6
39	18	0	18	3	0	1	1	1	1	1	1	6
40	18	18	0	0	3	1	1	1	1	1	1	6
41	0	18	18	0	3	1	1	1	1	1	1	6
42	18	0	18	0	3	1	1	1	1	1	1	6
43	12	12	12	2	1	1	1	1	1	1	1	6
44	12	12	12	1	2	1	1	1	1	1	1	6
45	12	12	12	2	1	1	1	1	1	1	1	6
46	12	12	12	3	0	1	1	1	1	1	1	6
47	12	12	12	3	0	1	1	1	1	1	1	6
48	12	12	12	3	0	1	1	1	1	1	1	6
49	12	12	12	0	3	1	1	1	1	1	1	6
50	12	12	12	0	3	1	1	1	1	1	1	6
51	12	12	12	0	3	1	1	1	1	1	1	6

The "Straw Model" sheet, including situational (host nation/base) inputs but *less* the breakout of force mix composition and suitability (in the actual spreadsheet). This sheet is the input for the "Scored Force Mixes" formula sheet as well as the "*Go / No Go*" filter sheet.

HOST NATION: Republic of Cantonia
STAGING BASE: Blue Coral AB, ROC

	STATUS	FA	FB	FC	B1	B2
MULTI-NATIONAL COMPATIBILITY:	No Mult.	0.7	0.9	0.8	0.9	0.7
DISTANCE FROM TARGETS:	900	0.9	1	1.1	2.5	2.7
MUNITIONS STORAGE CAPACITY:	0.95	0.95	0.75	0.85	0.7	0.8
POL CAPACITY:	0.9	0.8	0.9	0.75	0.8	0.7
TANKER AVAILABILITY:	0.9					
TOPOGRAPHY IMPACT:	0.2					
CLIMATE IMPACT:	0.22					
ENEMY CAPABILITY:	33					
ENEMY ISR MULTIPLIER:	0.4	0.15	0.2	0.25	0.22	0.11
ENEMY INTERFERENCE IMPACT:	0.3					
90-DAY RUNNING MC RATE OF MDS:	No Mult.	0.92	0.83	0.8	0.75	0.84

* BLUE PRINT: SPECIFIC TO HOST BASE
(GUI idea: user can scroll a list of MDS's, gain 90-day MC rate and particular Multi-National Compatibility score--Perfect for ALP's real time info networ
ALP's real time logistics architecture can have ALL of the BLUE data for host bases continually updated, to be displayed and calculated within model automatically upon base selection.

Multi-National	**Beddown Fighter**	**Beddown Bomber**	**Resupply**	**MSA Fighter**	**MSA Bomber**	**POL**	**Flexibility**	**Utilization**	**Tanker Support**	**Topography**	**Climate**	**MC Rate**	**Enemy Capability**	**Enemy ISR**	**Enemy Interference**
0.84	0.87	2.25	0.83	0.78	0.66	0.78	0.83	0.32	0.70	0.16	0.16	0.85	1.18	0.07	0.24
0.78	0.84	2.25	0.77	0.84	0.66	0.75	0.79	0.29	0.67	0.17	0.15	0.88	1.18	0.07	0.26
0.76	0.84	2.43	0.77	0.84	0.76	0.74	0.78	0.28	0.68	0.17	0.16	0.89	1.18	0.06	0.26
0.82	0.87	2.43	0.84	0.78	0.76	0.77	0.82	0.31	0.70	0.16	0.16	0.86	1.18	0.07	0.24
0.78	0.93	2.25	0.77	0.84	0.66	0.69	0.72	0.27	0.76	0.17	0.18	0.83	1.18	0.09	0.22
0.84	0.96	2.25	0.83	0.78	0.66	0.72	0.76	0.31	0.78	0.16	0.19	0.81	1.18	0.09	0.21
0.76	0.93	2.43	0.77	0.84	0.76	0.69	0.71	0.27	0.76	0.17	0.18	0.84	1.18	0.08	0.22
0.82	0.96	2.43	0.84	0.78	0.76	0.71	0.74	0.30	0.79	0.17	0.19	0.81	1.18	0.09	0.21
0.87	0.93	2.25	0.86	0.74	0.66	0.76	0.81	0.33	0.76	0.16	0.18	0.81	1.18	0.09	0.22
0.75	0.87	2.25	0.73	0.87	0.66	0.71	0.74	0.27	0.70	0.18	0.16	0.87	1.18	0.07	0.24
0.85	0.93	2.43	0.87	0.74	0.76	0.75	0.80	0.32	0.76	0.16	0.18	0.82	1.18	0.08	0.22
0.73	0.87	2.43	0.74	0.87	0.76	0.70	0.73	0.26	0.70	0.18	0.16	0.88	1.18	0.07	0.25
0.83	0.87	2.31	0.83	0.78	0.70	0.77	0.83	0.32	0.70	0.16	0.16	0.85	1.18	0.07	0.24
0.77	0.84	2.37	0.77	0.84	0.73	0.74	0.79	0.28	0.68	0.17	0.15	0.88	1.18	0.07	0.26
0.77	0.84	2.31	0.77	0.84	0.70	0.75	0.79	0.29	0.67	0.17	0.15	0.88	1.18	0.07	0.26
0.83	0.87	2.37	0.83	0.78	0.73	0.77	0.82	0.31	0.70	0.16	0.16	0.86	1.18	0.07	0.24
0.77	0.93	2.31	0.77	0.84	0.70	0.69	0.72	0.27	0.76	0.17	0.18	0.84	1.18	0.09	0.22
0.83	0.96	2.37	0.83	0.78	0.73	0.72	0.75	0.30	0.79	0.17	0.19	0.81	1.18	0.09	0.21
0.77	0.93	2.31	0.77	0.84	0.70	0.69	0.72	0.27	0.76	0.17	0.18	0.84	1.18	0.09	0.22
0.83	0.96	2.37	0.83	0.78	0.73	0.72	0.75	0.30	0.79	0.17	0.19	0.81	1.18	0.09	0.21
0.86	0.93	2.31	0.86	0.74	0.70	0.76	0.81	0.33	0.76	0.16	0.18	0.82	1.18	0.09	0.22
0.74	0.87	2.37	0.74	0.87	0.73	0.70	0.73	0.26	0.70	0.18	0.16	0.87	1.18	0.07	0.25
0.86	0.93	2.31	0.86	0.74	0.70	0.76	0.81	0.33	0.76	0.16	0.18	0.82	1.18	0.09	0.22
0.74	0.87	2.37	0.74	0.87	0.73	0.70	0.73	0.26	0.70	0.18	0.16	0.87	1.18	0.07	0.25
0.72	0.81	2.25	0.70	0.90	0.66	0.72	0.76	0.26	0.65	0.18	0.14	0.91	1.18	0.06	0.27
0.70	0.81	2.43	0.71	0.90	0.76	0.71	0.74	0.25	0.65	0.18	0.15	0.91	1.18	0.06	0.27
0.71	0.81	2.31	0.71	0.90	0.70	0.72	0.75	0.25	0.65	0.18	0.15	0.91	1.18	0.06	0.27
0.90	0.90	2.25	0.89	0.71	0.66	0.80	0.87	0.35	0.73	0.15	0.17	0.82	1.18	0.08	0.23
0.88	0.90	2.43	0.90	0.71	0.76	0.80	0.86	0.34	0.73	0.16	0.17	0.83	1.18	0.08	0.23
0.89	0.90	2.37	0.89	0.71	0.73	0.80	0.86	0.34	0.73	0.16	0.17	0.83	1.18	0.08	0.23
0.81	0.91	2.25	0.80	0.75	0.66	0.68	0.70	0.28	0.81	0.17	0.19	0.80	1.18	0.10	0.20
0.79	0.99	2.43	0.81	0.81	0.76	0.67	0.69	0.28	0.81	0.17	0.20	0.80	1.18	0.10	0.20
0.80	0.94	2.31	0.80	0.77	0.70	0.68	0.70	0.28	0.81	0.17	0.19	0.80	1.18	0.10	0.20
0.80	0.83	2.37	0.80	0.79	0.73	0.76	0.80	0.30	0.69	0.17	0.16	0.87	1.18	0.07	0.25
0.85	0.90	2.31	0.85	0.72	0.70	0.74	0.78	0.31	0.77	0.16	0.18	0.81	1.18	0.09	0.22
0.75	0.88	2.37	0.76	0.83	0.73	0.69	0.72	0.27	0.73	0.18	0.17	0.86	1.18	0.08	0.23
0.81	0.79	2.25	0.80	0.75	0.66	0.76	0.81	0.30	0.69	0.17	0.16	0.87	1.18	0.07	0.25
0.85	0.87	2.25	0.84	0.70	0.66	0.74	0.78	0.32	0.77	0.16	0.18	0.81	1.18	0.09	0.21
0.76	0.83	2.25	0.75	0.79	0.66	0.70	0.73	0.27	0.73	0.17	0.17	0.85	1.18	0.08	0.23
0.79	0.86	2.43	0.81	0.81	0.76	0.75	0.80	0.30	0.69	0.17	0.16	0.87	1.18	0.07	0.25
0.84	0.95	2.43	0.85	0.76	0.76	0.73	0.77	0.31	0.77	0.16	0.18	0.82	1.18	0.09	0.22
0.75	0.90	2.43	0.76	0.86	0.76	0.69	0.72	0.26	0.73	0.18	0.17	0.86	1.18	0.08	0.23
0.80	0.85	2.31	0.80	0.77	0.70	0.73	0.77	0.29	0.73	0.17	0.17	0.84	1.18	0.08	0.23
0.80	0.88	2.37	0.80	0.79	0.73	0.73	0.77	0.29	0.73	0.17	0.17	0.85	1.18	0.08	0.23
0.80	0.85	2.31	0.80	0.77	0.70	0.73	0.77	0.29	0.73	0.17	0.17	0.84	1.18	0.08	0.23
0.81	0.83	2.25	0.80	0.75	0.66	0.73	0.78	0.30	0.73	0.17	0.17	0.84	1.18	0.08	0.23
0.81	0.83	2.25	0.80	0.75	0.66	0.73	0.78	0.30	0.73	0.17	0.17	0.84	1.18	0.08	0.23
0.81	0.83	2.25	0.80	0.75	0.66	0.73	0.78	0.30	0.73	0.17	0.17	0.84	1.18	0.08	0.23
0.79	0.90	2.43	0.81	0.81	0.76	0.73	0.76	0.29	0.73	0.17	0.17	0.85	1.18	0.08	0.23
0.79	0.90	2.43	0.81	0.81	0.76	0.73	0.76	0.29	0.73	0.17	0.17	0.85	1.18	0.08	0.23
0.79	0.90	2.43	0.81	0.81	0.76	0.73	0.76	0.29	0.73	0.17	0.17	0.85	1.18	0.08	0.23

"Input Sheet" for the Straw Model:

*Based upon notional suitability ratings for required missions AA, AG, and PB, the five available aircraft are mixed into candidate forces that *meet* the *mandatory* mission capability for day X. Each force mix then produces its own suitability score. The combination of suitability and capability comprise an *intrinsic* value. The suitability scores and rankings of scores in the right hand columns are not to be confused with overall intrinsic values.

SUITABILITY

	FA	FB	FC	B1	B2
AA	0.8	0.3	0.6	0.001	0.001
AG	0.4	0.8	0.6	0.001	0.001
PB	0.001	0.001	0.1	0.8	0.4

CAPABILITY

AA	AG	PB
10	20	2

FA			FB			FC			B1			B2		
AA	AG	PB	AA	AG	PB	AA	AG	PB	AA	AG	PB	AA	AG	PB
10				20							2			
	20		10								2			
	20		10											2
10				20										2
10							20				2			
			10				20				2			
10							20							2
			10				20							2
				20		10					2			
	20					10					2			
				20		10								2
	20					10								2
10				20							1			1
	20		10								1			1
	20		10								1			1
10				20							1			1
10							20				1			1
			10				20				1			1
10							20				1			1
			10				20				1			1
				20		10					1			1
	20					10					1			1
				20		10					1			1
	20					10					1			1
10	20										2			
10	20													2
10	20										1			1
			10	20							2			
			10	20										2
			10	20							1			1
						10	20				2			
						10	20							2
						10	20				1			1
5	10		5	10							1			1
			5	10		5	10				1			1
5	10					5	10				1			1
5	10		5	10							2			
			5	10		5	10				2			
5	10					5	10				2			
5	10		5	10										2
			5	10		5	10							2
5	10					5	10							2
5	5		5	5			10				1			1
	10		5	5		5	5				1			1
5	5			10		5	5				1			1
5	5		5	5			10				2			
	10		5	5		5	5				2			
5	5			10		5	5				2			
5	5		5	5			10							2
	10		5	5		5	5							2
5	5			10		5	5							2

MIX	FA	FB	FC	B1	B2	Suitability Score	Rank
1	12	24	0	3	0	25.6	1
2	24	12	0	3	0	12.6	48
3	24	12	0	0	3	11.8	51
4	12	24	0	0	3	24.8	4
5	12	0	24	3	0	21.6	9
6	0	12	24	3	0	16.6	39
7	12	0	24	0	3	20.8	14
8	0	12	24	0	3	15.8	43
9	0	24	12	3	0	23.6	5
10	24	0	12	3	0	15.6	44
11	0	24	12	0	3	22.8	8
12	24	0	12	0	3	14.8	47
13	12	24	0	2	1	25.2	2
14	24	12	0	1	2	12.2	49
15	24	12	0	2	1	12.2	49
16	12	24	0	1	2	25.2	2
17	12	0	24	2	1	21.2	11
18	0	12	24	1	2	16.2	41
19	12	0	24	2	1	21.2	11
20	0	12	24	1	2	16.2	41
21	0	24	12	2	1	23.2	6
22	24	0	12	1	2	15.2	45
23	0	24	12	2	1	23.2	6
24	24	0	12	1	2	15.2	45
25	36	0	0	3	0	17.6	34
26	36	0	0	0	3	16.8	37
27	36	0	0	2	1	17.2	35
28	0	36	0	3	0	20.6	16
29	0	36	0	0	3	19.8	19
30	0	36	0	1	2	20.2	17
31	0	0	36	3	0	19.6	21
32	0	0	36	0	3	18.8	26
33	0	0	36	2	1	19.2	23
34	18	18	0	1	2	18.7	27
35	0	18	18	2	1	19.7	20
36	18	0	18	1	2	18.2	32
37	18	18	0	3	0	19.1	24
38	0	18	18	3	0	20.1	18
39	18	0	18	3	0	18.6	29
40	18	18	0	0	3	18.3	30
41	0	18	18	0	3	19.3	22
42	18	0	18	0	3	17.8	33
43	12	12	12	2	1	18.7	27
44	12	12	12	1	2	16.7	38
45	12	12	12	2	1	21.2	11
46	12	12	12	3	0	19.1	24
47	12	12	12	3	0	17.1	36
48	12	12	12	3	0	21.6	9
49	12	12	12	0	3	18.3	30
50	12	12	12	0	3	16.3	40
51	12	12	12	0	3	20.8	14

Appendix L: The Subject Matter Expert Pool

Col. Joel Petersen
Lt. Col. Larry Brockshus
Mr. Gary Hitz
Mr. William Mattson
Lt. Col. Connie Vandermarliere
Lt. Col. Michael Duvall
Lt. Col. Petitto McMahon
Maj. Dennis McDevitt
Maj. William Carter
Maj. Gregory Broardt
Maj. Lou Kaelin
Lt. Col. William Doneth
Maj. Thomas Nankervis
Mr. Jeffrey Brown
Mr. Don Niederkopfler
Lt. Col. Barrett Clay
Lt. Col. N. Gonzalez
Maj. Steven Wackowski
Col. Kenneth Poole
Lt. Col. Bryan Johnson
Maj. Kirby Locklear
Mr. Clay Olschner
Mr. Michael Urban
Maj. Chuck McCleen
Lt. Col. Marty Spitek
Col. Ernest Howard
Col. Shirley Rawls
Lt. Col. Raymond Santiago
Maj. Laletta Tatum
Mr. Robert Barthelmess
Dr. Adolph Perry
Maj. J. D. Haas
Lt. Col. John Stankowski, III
Lt. Col. Burrell Jones, III

Appendix M: Visual Basic Coding for SDVF's

The following code for Microsoft Excel Visual Basic was provided by Kirkwood for converting hand-drawn value function elicitations into exponential or piecewise linear value function curves [Kirkwood, 1997: 81].

```
Sub kirkwood (expon)

Function  ValueE(x, low, high, monotonicity, rho)
' Determines the value score for an expon value function

Select Case UCase(monotonicity)
 Case "I"
        delta = x - low
 Case "D"
        delta = high - x
End Select

If UCase(rho) = "INF" Then
        ValueE = delta / (high - low)
Else
        ValueE = (1 - Exp(-delta / rho)) / (1 - Exp(-(high - low) / rho))
End If

End Function


Function ValuePL(x, Xi, Vi)
' Determines the value score for a piecewise linear function

 i = 2
 Do While x > Xi(i)
 i = i + 1
 Loop
ValuePL = Vi(i - 1) + (Vi(i) - Vi(i - 1)) * _
        (x - Xi(i - 1)) / (Xi(i) - Xi(i - 1))

End Function
```

Appendix N: Excel Formulas Used to Incorporate the 16 SDVF's

*The first two formulas provide short explanations. The MSA factors for Bombers and Fighters, as well as the Distance factors for both, are complementary in their weighting. The short explanation provided for "Beddown Location—Fighter Distance" (second, below) also pertains to "MSA—Fighter," "MSA—Bomber," and "Beddown Location—Bomber."

Excel Formula for scoring the "Multi-National Compatibility" SDVF vs. a candidate force mix:

=$D$4*IF('Constraint Filter'!$AA3>0,IF('Straw Model'!V4>'Multi-National Compatibility'!$AE$11,1,IF('Straw Model'!V4>'Multi-National Compatibility'!$AE$12,0.5+0.5*ValueE('Straw Model'!V4,'Multi-National Compatibility'!$AE$12,'Multi-National Compatibility'!$AE$11,"I",'Multi-National Compatibility'!$AH$12),0.5*ValueE('Straw Model'!V4,'Multi-National Compatibility'!$AE$13,'Multi-National Compatibility'!$AE$12,"I",'Multi-National Compatibility'!$AH$13))),0)

Where the first shaded area is the global weight, the second shaded area is the *go / no go* feasibility multiplier. The IF statements compute different segments along the value function's curve, and the shaded multipliers maintain value advancement along the curve.

Excel Formula for scoring the "Beddown Location—Fighter Distance" SDVF vs. a candidate force mix:

=(($E$4*(SUM('Straw Model'!P4:R4)/('Straw Model'!O4)))+('Scored Force Mixes'!$F$4-((SUM('Straw Model'!S4:T4))/'Straw Model'!O4)*'Scored Force Mixes'!$F$4))*IF('Constraint Filter'!$AA3>0,IF('Straw Model'!W4<'Beddown Fighter'!$AJ$11,1,IF('Straw Model'!W4<'Beddown Fighter'!$AJ$12,ValueE('Straw Model'!W4,'Beddown Fighter'!$AJ$11,'Beddown Fighter'!$AJ$12,"D",'Beddown Fighter'!$AM$12),0)),0)

Where the first shaded area represents a complementary relationship between this factor's weight and that of "Bomber Distance." It is this factor's weight times its percent of the force mix plus the sum-product of the other factor's weight minus its percentage of the force mix times its weight. Other components of the formula are similar to the "multi-National Compatibility" factor's formula.

Excel Formula for scoring the “Beddown Location—Bomber Distance” SDVF vs. a candidate force mix:

```
=(($F$4*(SUM('Straw Model'!S4:T4))/'Straw Model'!O4)+($E$4-((SUM('Straw
Model'!P4:R4))/('Straw Model'!O4))*('Scored Force
Mixes'!$E$4)))*(IF('Constraint Filter'!AA3>0,IF('Straw Model'!X4<'Beddown
Bomber'!$AJ$11,1,IF('Straw Model'!X4<'Beddown Bomber'!$AJ$12,
ValueE('Straw Model'!X4,'Beddown Bomber'!$AJ$11,'Beddown
Bomber'!$AJ$12,"D",'Beddown Bomber'!$AM$12),0)),0))
```

Excel Formula for scoring the “Resupply” SDVF vs. a candidate force mix:

```
=$G$4*IF('Constraint Filter'!$AA3>0,IF('Straw Model'!Y4<'Ability to
Resupply'!$AJ$11,0.18*ValueE('Straw Model'!Y4,'Ability to
Resupply'!$AJ$11,'Ability to Resupply'!$AJ$10,"D",'Ability to
Resupply'!$AM$11),IF('Straw Model'!Y4<'Ability to
Resupply'!$AJ$12,ValuePL('Straw Model'!Y4,'Ability to
Resupply'!$AJ$11:$AJ$12,'Ability to
Resupply'!$AK$11:$AK$12),0.62+0.38*ValueE('Straw Model'!Y4,'Ability to
Resupply'!$AJ$13,'Ability to Resupply'!$AJ$12,"D",'Ability to
Resupply'!$AM$13))),0)
```

Excel Formula for scoring the “MSA—Fighter” SDVF vs. a candidate force mix:

```
=(($H$4*((SUM('Straw Model'!P4:R4))/('Straw Model'!O4)))+(('Scored Force
Mixes'!$I$4)-(((SUM('Straw Model'!S4:T4))/('Straw Model'!O4))*('Scored Force
Mixes'!$I$4))))*(IF('Constraint Filter'!$AA3>0,IF('Straw
Model'!Z4<MSA_Fighter!$AJ$11,0.5*ValueE('Straw
Model'!Z4,MSA_Fighter!$AJ$10,MSA_Fighter!$AJ$11,"I",MSA_Fighter!$AM$
11),0.5+0.5*ValueE('Straw
Model'!Z4,MSA_Fighter!$AJ$11,MSA_Fighter!$AJ$12,"I",MSA_Fighter!$AM$
12)),0))
```

Excel Formula for scoring the "MSA—Bomber" SDVF vs. a candidate force mix:

```
=(($I$4*((SUM('Straw Model'!S4:T4))/('Straw Model'!O4)))+(('Scored Force
Mixes'!$H$4)-(((SUM('Straw Model'!P4:R4))/('Straw Model'!O4))*('Scored
Force Mixes'!$H$4))))*(IF('Constraint Filter'!$AA3>0,IF('Straw
Model'!AA4<MSA_Bomber!$AJ$11,0.5*ValueE('Straw
Model'!AA4,MSA_Bomber!$AJ$10,MSA_Bomber!$AJ$11,"I",MSA_Bomber!$
AM$11),0.5+0.5*ValueE('Straw
Model'!AA4,MSA_Bomber!$AJ$11,MSA_Bomber!$AJ$12,"I",MSA_Bomber!$
AM$12)),0))
```

Excel Formula for scoring the "POL" SDVF vs. a candidate force mix:

```
=$J$4*IF('Constraint Filter'!$AA3>0,IF('Straw
Model'!AB4<POL!$AJ$11,0.5*ValueE('Straw
Model'!AB4,POL!$AJ$10,POL!$AJ$11,"I",POL!$AM$11),0.5+0.5*ValueE('Stra
w Model'!AB4,POL!$AJ$11,POL!$AJ$12,"I",POL!$AM$12)),0)
```

Excel Formula for scoring the "Inter-Mission Flexibility" SDVF vs. a candidate force mix:

```
=$K$4*IF('Constraint Filter'!$AA3>0,IF('Straw
Model'!AC4<Flexibility!$AJ$11,ValueE('Straw
Model'!AC4,Flexibility!$AJ$10,Flexibility!$AJ$11,"I",Flexibility!$AM$11),1),0)
```

Excel Formula for scoring the "Force Mix Utilization" SDVF vs. a candidate force mix:

```
=$L$4*IF('Constraint Filter'!$AA3>0,IF('Straw
Model'!AD4<Utilization!$AJ$11,1,IF('Straw
Model'!AD4<Utilization!$AJ$12,ValuePL('Straw
Model'!AD4,Utilization!$AJ$11:$AJ$12,Utilization!$AK$11:$AK$12),0.94*Val
ueE('Straw
Model'!AD4,Utilization!$AJ$12,Utilization!$AJ$13,"D",Utilization!$AM$13))),
0)
```

Excel Formula for scoring the "Tanker Support Available" SDVF vs. a candidate force mix:

```
=$M$4*IF('Constraint Filter'!$AA3>0,IF('Straw Model'!AE4<'Tanker
Support'!$AJ$11,ValueE('Straw Model'!AE4,'Tanker Support'!$AJ$10,'Tanker
Support'!$AJ$11,"I",'Tanker Support'!$AM$11),1),0)
```

Excel Formula for scoring the "Operating Location—Topography" SDVF vs. a candidate force mix:

```
=$N$4*IF('Constraint Filter'!$AA3>0,IF('Straw
Model'!AF4<Topography!$AJ$11,ValueE('Straw
Model'!AF4,Topography!$AJ$10,Topography!$AJ$11,"D",Topography!$AM$11
),0),0)
```

Excel Formula for scoring the "Operating Location—Climate" SDVF vs. a candidate force mix:

```
=$O$4*IF('Constraint Filter'!$AA3>0,IF('Straw
Model'!AG4<Climate!$AJ$11,ValueE('Straw
Model'!AG4,Climate!$AJ$10,Climate!$AJ$11,"D",Climate!$AM$11),0),0)
```

Excel Formula for scoring the "Force Mix MC Rate" SDVF vs. a candidate force mix:

```
=$P$4*IF('Constraint Filter'!$AA3>0,IF('Straw
Model'!AH4<Availability!$AJ$11,0,IF('Straw
Model'!AH4<Availability!$AJ$12,0.4*ValueE('Straw
Model'!AH4,Availability!$AJ$11,Availability!$AJ$12,"I",Availability!$AM$12),
IF('Straw Model'!AH4<Availability!$AJ$13,0.4+0.6*ValueE('Straw
Model'!AH4,Availability!$AJ$12,Availability!$AJ$13,"I",Availability!$AM$13),
1))),0)
```

Excel Formula for scoring the "Enemy Capability" SDVF vs. a candidate force mix:

=$Q$4*IF('Constraint Filter'!$AA3>0,IF('Straw Model'!AI4<'Enemy Capability'!$AJ$11,0,IF('Straw Model'!AI4<'Enemy Capability'!$AJ$12,0.42*ValueE('Straw Model'!AI4,'Enemy Capability'!$AJ$11,'Enemy Capability'!$AJ$12,"I",'Enemy Capability'!$AM$12),IF('Straw Model'!AI4<'Enemy Capability'!$AJ$13,0.42+0.58*ValueE('Straw Model'!AI4,'Enemy Capability'!$AJ$12,'Enemy Capability'!$AJ$13,"I",'Enemy Capability'!$AM$13),1))),0)

Excel Formula for scoring the "Enemy ISR" SDVF vs. a candidate force mix:

=$R$4*IF('Constraint Filter'!$AA3>0,IF('Straw Model'!AJ4<'Enemy ISR'!$AJ$11,ValueE('Straw Model'!AJ4,'Enemy ISR'!$AJ$10,'Enemy ISR'!$AJ$11,"D",'Enemy ISR'!$AM$11),0),0)

Excel Formula for scoring the "Enemy Interference" SDVF vs. a candidate force mix:

=$S$4*IF('Constraint Filter'!$AA3>0,IF('Straw Model'!AK4<'Enemy Interference'!$AJ$11,0.5+0.5*ValueE('Straw Model'!AK4,'Enemy Interference'!$AJ$10,'Enemy Interference'!$AJ$11,"D",'Enemy Interference'!$AM$11),IF('Straw Model'!AK4<'Enemy Interference'!$AJ$12,0.5*ValueE('Straw Model'!AK4,'Enemy Interference'!$AJ$11,'Enemy Interference'!$AJ$12,"D",'Enemy Interference'!$AM$12),0)),0)

Appendix O: External Sensitivity Analyses

MIX	Extrin @ Typical	Rank	(suitability) Intrin @ Typical	Rank	Multiplic. Result	Rank
1	0.713534	15	25.6	1	18.26647	1
2	0.714978	8	12.6	48	9.008728	48
3	0.71603	2	11.8	51	8.449152	51
4	0.714309	9	24.8	4	17.71487	4
5	0.710151	34	21.6	9	15.33927	9
6	0.70924	38	16.6	39	11.77338	39
7	0.711153	25	20.8	14	14.79197	15
8	0.709751	35	15.8	43	11.21406	43
9	0.710476	30	23.6	5	16.76722	5
10	0.712788	16	15.6	44	11.11949	44
11	0.711142	26	22.8	8	16.21403	8
12	0.714035	10	14.8	47	10.56772	47
13	0.713743	12	25.2	2	17.98633	3
14	0.715651	4	12.2	49	8.730945	49
15	0.715283	5	12.2	49	8.726451	50
16	0.71402	11	25.2	2	17.9933	2
17	0.710439	31	21.2	11	15.06131	11
18	0.709478	36	16.2	41	11.49355	41
19	0.710439	31	21.2	11	15.06131	11
20	0.709478	36	16.2	41	11.49355	41
21	0.710648	27	23.2	6	16.48703	6
22	0.713594	13	15.2	45	10.84662	45
23	0.710648	27	23.2	6	16.48703	6
24	0.713594	13	15.2	45	10.84662	45
25	0.715222	6	17.6	34	12.58791	34
26	0.716797	1	16.8	37	12.04219	36
27	0.715707	3	17.2	35	12.31016	35
28	0.711992	23	20.6	16	14.66704	16
29	0.712621	20	19.8	19	14.10989	18
30	0.712379	22	20.2	17	14.39005	17
31	0.70073	50	19.6	21	13.7343	21
32	0.710606	29	18.8	26	13.3594	26
33	0.70368	45	19.2	23	13.51066	23
34	0.71145	24	18.7	27	13.30412	27
35	0.704337	44	19.7	20	13.87544	20
36	0.708184	40	18.2	32	12.88894	32
37	0.704945	43	19.1	24	13.46444	24
38	0.701729	49	20.1	18	14.10476	19
39	0.700554	51	18.6	29	13.03031	31
40	0.71521	7	18.3	30	13.08835	29
41	0.710439	33	19.3	22	13.71147	22
42	0.712593	21	17.8	33	12.68415	33
43	0.705602	41	18.7	27	13.19475	28
44	0.70902	39	16.7	38	11.84063	38
45	0.705602	41	21.2	11	14.95876	13
46	0.702531	46	19.1	24	13.41834	25
47	0.702531	46	17.1	36	12.01328	37
48	0.702531	46	21.6	9	15.17466	10
49	0.712772	17	18.3	30	13.04373	30
50	0.712772	17	16.3	40	11.61819	40
51	0.712772	17	20.8	14	14.82566	14

MIX	Extrin @ Typical	Rank	(suitability) Intrin @ .9 and .1	Rank	Multiplic. Result	Rank
1	0.713534	15	28.8	1	20.54978	1
2	0.714978	8	4.8	44	3.431896	44
3	0.71603	2	3.2	50	2.291295	50
4	0.714309	9	27.2	7	19.42921	7
5	0.710151	34	12.8	21	9.089935	23
6	0.70924	38	4.8	44	3.404351	45
7	0.711153	25	11.2	37	7.964909	42
8	0.709751	35	3.2	50	2.271203	51
9	0.710476	30	28.8	1	20.4617	2
10	0.712788	16	12.8	21	9.123686	22
11	0.711142	26	27.2	7	19.34305	8
12	0.714035	10	11.2	37	7.997193	38
13	0.713743	12	28	3	19.98481	4
14	0.715651	4	4	46	2.862605	46
15	0.715283	5	4	46	2.861131	47
16	0.71402	11	28	3	19.99255	3
17	0.710439	31	12	28	8.525268	31
18	0.709478	36	4	46	2.837913	48
19	0.710439	31	12	28	8.525268	31
20	0.709478	36	4	46	2.837913	48
21	0.710648	27	28	3	19.89813	5
22	0.713594	13	12	28	8.563124	29
23	0.710648	27	28	3	19.89813	5
24	0.713594	13	12	28	8.563124	29
25	0.715222	6	12.8	21	9.154844	21
26	0.716797	1	11.2	37	8.028124	37
27	0.715707	3	12	28	8.58848	28
28	0.711992	23	20.8	9	14.80944	9
29	0.712621	20	19.2	13	13.68232	14
30	0.712379	22	20	11	14.24757	11
31	0.70073	50	12.8	21	8.969341	26
32	0.710606	29	11.2	37	7.958791	43
33	0.70368	45	12	28	8.444161	36
34	0.71145	24	16	17	11.3832	17
35	0.704337	44	16	17	11.2694	18
36	0.708184	40	12	28	8.498204	34
37	0.704945	43	16.8	15	11.84307	15
38	0.701729	49	16.8	15	11.78905	16
39	0.700554	51	12.8	21	8.967096	27
40	0.71521	7	15.2	19	10.8712	19
41	0.710439	33	15.2	19	10.79867	20
42	0.712593	21	11.2	37	7.981041	41
43	0.705602	41	12	28	8.46722	35
44	0.70902	39	12	28	8.508238	33
45	0.705602	41	20	11	14.11203	12
46	0.702531	46	12.8	21	8.992394	24
47	0.702531	46	12.8	21	8.992394	24
48	0.702531	46	20.8	9	14.61264	10
49	0.712772	17	11.2	37	7.983048	39
50	0.712772	17	11.2	37	7.983048	39
51	0.712772	17	19.2	13	13.68523	13

			(suitability)			
	Extrin @		Intrin @		Multiplic.	
MIX	**Typical**	Rank	**.8 and .2**	Rank	Result	Rank
1	0.713534	15	25.6	1	18.26647	1
2	0.714978	8	7.6	44	5.433836	44
3	0.71603	2	6.4	50	4.582591	50
4	0.714309	9	24.4	7	17.42915	7
5	0.710151	34	13.6	21	9.658056	23
6	0.70924	38	7.6	44	5.390222	45
7	0.711153	25	12.4	37	8.818292	42
8	0.709751	35	6.4	50	4.542406	51
9	0.710476	30	25.6	1	18.18817	2
10	0.712788	16	13.6	21	9.693916	22
11	0.711142	26	24.4	7	17.35186	8
12	0.714035	10	12.4	37	8.854035	38
13	0.713743	12	25	3	17.84358	4
14	0.715651	4	7	46	5.009559	46
15	0.715283	5	7	46	5.00698	47
16	0.71402	11	25	3	17.85049	3
17	0.710439	31	13	28	9.235707	31
18	0.709478	36	7	46	4.966347	48
19	0.710439	31	13	28	9.235707	31
20	0.709478	36	7	46	4.966347	48
21	0.710648	27	25	3	17.76619	5
22	0.713594	13	13	28	9.276717	29
23	0.710648	27	25	3	17.76619	5
24	0.713594	13	13	28	9.276717	29
25	0.715222	6	13.6	21	9.727022	21
26	0.716797	1	12.4	37	8.88828	37
27	0.715707	3	13	28	9.304187	28
28	0.711992	23	19.6	9	13.95505	9
29	0.712621	20	18.4	13	13.11222	14
30	0.712379	22	19	11	13.53519	11
31	0.70073	50	13.6	21	9.529924	26
32	0.710606	29	12.4	37	8.811518	43
33	0.70368	45	13	28	9.147841	36
34	0.71145	24	16	17	11.3832	17
35	0.704337	44	16	17	11.2694	18
36	0.708184	40	13	28	9.206388	34
37	0.704945	43	16.6	15	11.70208	15
38	0.701729	49	16.6	15	11.64871	16
39	0.700554	51	13.6	21	9.52754	27
40	0.71521	7	15.4	19	11.01424	19
41	0.710439	33	15.4	19	10.94076	20
42	0.712593	21	12.4	37	8.836152	41
43	0.705602	41	13	28	9.172822	35
44	0.70902	39	13	28	9.217258	33
45	0.705602	41	19	11	13.40643	12
46	0.702531	46	13.6	21	9.554419	24
47	0.702531	46	13.6	21	9.554419	24
48	0.702531	46	19.6	9	13.7696	10
49	0.712772	17	12.4	37	8.838375	39
50	0.712772	17	12.4	37	8.838375	39
51	0.712772	17	18.4	13	13.11501	13

			(suitability)			
	Extrin @		Intrin @		Multiplic.	
MIX	**Typical**	Rank	**.7 and .3**	Rank	Result	Rank
1	0.713534	15	22.4	1	15.98316	1
2	0.714978	8	10.4	44	7.435775	44
3	0.71603	2	9.6	50	6.873886	50
4	0.714309	9	21.6	7	15.42908	7
5	0.710151	34	14.4	21	10.22618	23
6	0.70924	38	10.4	44	7.376093	45
7	0.711153	25	13.6	37	9.671675	42
8	0.709751	35	9.6	50	6.813609	51
9	0.710476	30	22.4	1	15.91465	2
10	0.712788	16	14.4	21	10.26415	22
11	0.711142	26	21.6	7	15.36066	8
12	0.714035	10	13.6	37	9.710877	38
13	0.713743	12	22	3	15.70235	4
14	0.715651	4	10	46	7.156512	46
15	0.715283	5	10	46	7.152828	47
16	0.71402	11	22	3	15.70844	3
17	0.710439	31	14	28	9.946146	31
18	0.709478	36	10	46	7.094782	48
19	0.710439	31	14	28	9.946146	31
20	0.709478	36	10	46	7.094782	48
21	0.710648	27	22	3	15.63425	5
22	0.713594	13	14	28	9.990311	29
23	0.710648	27	22	3	15.63425	5
24	0.713594	13	14	28	9.990311	29
25	0.715222	6	14.4	21	10.2992	21
26	0.716797	1	13.6	37	9.748436	37
27	0.715707	3	14	28	10.01989	28
28	0.711992	23	18.4	9	13.10066	9
29	0.712621	20	17.6	13	12.54212	14
30	0.712379	22	18	11	12.82281	11
31	0.70073	50	14.4	21	10.09051	26
32	0.710606	29	13.6	37	9.664246	43
33	0.70368	45	14	28	9.851521	36
34	0.71145	24	16	17	11.3832	17
35	0.704337	44	16	17	11.2694	18
36	0.708184	40	14	28	9.914571	34
37	0.704945	43	16.4	15	11.56109	15
38	0.701729	49	16.4	15	11.50836	16
39	0.700554	51	14.4	21	10.08798	27
40	0.71521	7	15.6	19	11.15728	19
41	0.710439	33	15.6	19	11.08285	20
42	0.712593	21	13.6	37	9.691264	41
43	0.705602	41	14	28	9.878424	35
44	0.70902	39	14	28	9.926278	33
45	0.705602	41	18	11	12.70083	12
46	0.702531	46	14.4	21	10.11644	24
47	0.702531	46	14.4	21	10.11644	24
48	0.702531	46	18.4	9	12.92657	10
49	0.712772	17	13.6	37	9.693702	39
50	0.712772	17	13.6	37	9.693702	39
51	0.712772	17	17.6	13	12.54479	13

MIX	Extrin @ Typical	Rank	(suitability) Intrin @ .6 and .4	Rank	Multiplic. Result	Rank
1	0.713534	15	19.2	1	13.69985	1
2	0.714978	8	13.2	44	9.437715	44
3	0.71603	2	12.8	50	9.165182	50
4	0.714309	9	18.8	7	13.42902	7
5	0.710151	34	15.2	21	10.7943	23
6	0.70924	38	13.2	44	9.361965	45
7	0.711153	25	14.8	37	10.52506	42
8	0.709751	35	12.8	50	9.084811	51
9	0.710476	30	19.2	1	13.64113	2
10	0.712788	16	15.2	21	10.83438	22
11	0.711142	26	18.8	7	13.36946	8
12	0.714035	10	14.8	37	10.56772	37
13	0.713743	12	19	3	13.56112	4
14	0.715651	4	13	46	9.303466	46
15	0.715283	5	13	46	9.298677	47
16	0.71402	11	19	3	13.56638	3
17	0.710439	31	15	28	10.65658	29
18	0.709478	36	13	46	9.223216	48
19	0.710439	31	15	28	10.65658	29
20	0.709478	36	13	46	9.223216	48
21	0.710648	27	19	3	13.50231	5
22	0.713594	13	15	28	10.7039	25
23	0.710648	27	19	3	13.50231	5
24	0.713594	13	15	28	10.7039	25
25	0.715222	6	15.2	21	10.87138	21
26	0.716797	1	14.8	37	10.60859	35
27	0.715707	3	15	28	10.7356	24
28	0.711992	23	17.2	9	12.24627	9
29	0.712621	20	16.8	13	11.97203	14
30	0.712379	22	17	11	12.11044	10
31	0.70073	50	15.2	21	10.65109	31
32	0.710606	29	14.8	37	10.51697	43
33	0.70368	45	15	28	10.5552	38
34	0.71145	24	16	17	11.3832	16
35	0.704337	44	16	17	11.2694	19
36	0.708184	40	15	28	10.62276	34
37	0.704945	43	16.2	15	11.42011	15
38	0.701729	49	16.2	15	11.36802	17
39	0.700554	51	15.2	21	10.64843	32
40	0.71521	7	15.8	19	11.30033	18
41	0.710439	33	15.8	19	11.22494	20
42	0.712593	21	14.8	37	10.54638	41
43	0.705602	41	15	28	10.58403	36
44	0.70902	39	15	28	10.6353	33
45	0.705602	41	17	11	11.99523	12
46	0.702531	46	15.2	21	10.67847	27
47	0.702531	46	15.2	21	10.67847	27
48	0.702531	46	17.2	9	12.08353	11
49	0.712772	17	14.8	37	10.54903	39
50	0.712772	17	14.8	37	10.54903	39
51	0.712772	17	16.8	13	11.97457	13

MIX	Extrin @ Typical	Rank	(suitability) Intrin @ .51 & .49	Rank	Multiplic. Result	Rank
1	0.713534	15	16.32	1	11.64487	1
2	0.714978	8	15.72	44	11.23946	38
3	0.71603	2	15.68	50	11.22735	41
4	0.714309	9	16.28	7	11.62896	4
5	0.710151	34	15.92	21	11.30561	28
6	0.70924	38	15.72	44	11.14925	48
7	0.711153	25	15.88	37	11.2931	32
8	0.709751	35	15.68	50	11.12889	51
9	0.710476	30	16.32	1	11.59496	5
10	0.712788	16	15.92	21	11.34758	20
11	0.711142	26	16.28	7	11.57739	8
12	0.714035	10	15.88	37	11.33888	23
13	0.713743	12	16.3	3	11.63402	3
14	0.715651	4	15.7	46	11.23572	39
15	0.715283	5	15.7	46	11.22994	40
16	0.71402	11	16.3	3	11.63852	2
17	0.710439	31	15.9	28	11.29598	29
18	0.709478	36	15.7	46	11.13881	49
19	0.710439	31	15.9	28	11.29598	29
20	0.709478	36	15.7	46	11.13881	49
21	0.710648	27	16.3	3	11.58356	6
22	0.713594	13	15.9	28	11.34614	21
23	0.710648	27	16.3	3	11.58356	6
24	0.713594	13	15.9	28	11.34614	21
25	0.715222	6	15.92	21	11.38634	14
26	0.716797	1	15.88	37	11.38273	16
27	0.715707	3	15.9	28	11.37974	17
28	0.711992	23	16.12	9	11.47732	9
29	0.712621	20	16.08	13	11.45894	12
30	0.712379	22	16.1	11	11.46929	10
31	0.70073	50	15.92	21	11.15562	46
32	0.710606	29	15.88	37	11.28443	33
33	0.70368	45	15.9	28	11.18851	43
34	0.71145	24	16	17	11.3832	15
35	0.704337	44	16	17	11.2694	35
36	0.708184	40	15.9	28	11.26012	36
37	0.704945	43	16.02	15	11.29322	31
38	0.701729	49	16.02	15	11.24171	37
39	0.700554	51	15.92	21	11.15283	47
40	0.71521	7	15.98	19	11.42906	13
41	0.710439	33	15.98	19	11.35281	19
42	0.712593	21	15.88	37	11.31598	27
43	0.705602	41	15.9	28	11.21907	42
44	0.70902	39	15.9	28	11.27342	34
45	0.705602	41	16.1	11	11.36019	18
46	0.702531	46	15.92	21	11.18429	44
47	0.702531	46	15.92	21	11.18429	44
48	0.702531	46	16.12	9	11.3248	24
49	0.712772	17	15.88	37	11.31882	25
50	0.712772	17	15.88	37	11.31882	25
51	0.712772	17	16.08	13	11.46138	11

MIX	Extrin @ .9 and .1	Rank	(suitability) Intrin @ Typical	Rank	Multiplic. Result	Rank
1	0.49235	41	25.6	1	12.60417	18
2	0.653574	18	12.6	48	8.235027	45
3	0.613193	30	11.8	51	7.235676	48
4	0.451663	47	24.8	4	11.20125	29
5	0.819733	1	21.6	9	17.70623	1
6	0.653574	18	16.6	39	10.84932	35
7	0.78455	13	20.8	14	16.31863	4
8	0.613193	30	15.8	43	9.688448	44
9	0.49235	41	23.6	5	11.61947	25
10	0.819733	1	15.6	44	12.78783	16
11	0.451663	47	22.8	8	10.29792	37
12	0.78455	13	14.8	47	11.61133	26
13	0.478048	43	25.2	2	12.04681	22
14	0.626065	26	12.2	49	7.637999	47
15	0.639323	23	12.2	49	7.799737	46
16	0.464825	46	25.2	2	11.71359	24
17	0.807273	6	21.2	11	17.11418	2
18	0.626065	26	16.2	41	10.14226	39
19	0.807273	6	21.2	11	17.11418	2
20	0.626065	26	16.2	41	10.14226	39
21	0.478048	43	23.2	6	11.09071	31
22	0.795755	10	15.2	45	12.09547	20
23	0.478048	43	23.2	6	11.09071	31
24	0.795755	10	15.2	45	12.09547	20
25	0.819733	1	17.6	34	14.4273	9
26	0.78455	13	16.8	37	13.18043	15
27	0.807273	8	17.2	35	13.88509	13
28	0.348434	49	20.6	16	7.177747	49
29	0.315672	51	19.8	19	6.250296	51
30	0.325735	50	20.2	17	6.579837	50
31	0.80881	4	19.6	21	15.85268	5
32	0.78455	13	18.8	26	14.74953	8
33	0.799638	9	19.2	23	15.35305	6
34	0.542366	38	18.7	27	10.14224	41
35	0.554912	37	19.7	20	10.93176	33
36	0.791744	12	18.2	32	14.40975	10
37	0.568733	35	19.1	24	10.8628	34
38	0.568733	35	20.1	18	11.43153	27
39	0.80881	4	18.6	29	15.04387	7
40	0.53048	39	18.3	30	9.707785	43
41	0.53048	39	19.3	22	10.23826	38
42	0.78455	13	17.8	33	13.96498	12
43	0.636165	24	18.7	27	11.89629	23
44	0.624431	29	16.7	38	10.428	36
45	0.636165	24	21.2	11	13.4867	14
46	0.648993	20	19.1	24	12.39576	19
47	0.648993	20	17.1	36	11.09778	30
48	0.648993	20	21.6	9	14.01825	11
49	0.613193	30	18.3	30	11.22143	28
50	0.613193	30	16.3	40	9.995044	42
51	0.613193	30	20.8	14	12.75441	17

MIX	Extrin @ .8 and .2	Rank	(suitability) Intrin @ Typical	Rank	Multiplic. Result	Rank
1	0.506263	41	25.6	1	12.96033	13
2	0.628016	18	12.6	48	7.913	46
3	0.597701	30	11.8	51	7.052869	51
4	0.476315	47	24.8	4	11.81262	22
5	0.755414	1	21.6	9	16.31695	1
6	0.628016	18	16.6	39	10.42506	36
7	0.72688	13	20.8	14	15.11911	4
8	0.597701	30	15.8	43	9.443672	44
9	0.506263	41	23.6	5	11.9478	20
10	0.755414	1	15.6	44	11.78446	23
11	0.476315	47	22.8	8	10.85999	32
12	0.72688	13	14.8	47	10.75783	33
13	0.495807	43	25.2	2	12.49435	16
14	0.607488	26	12.2	49	7.411354	49
15	0.617526	23	12.2	49	7.533814	48
16	0.485907	46	25.2	2	12.24487	18
17	0.745687	6	21.2	11	15.80857	2
18	0.607488	26	16.2	41	9.841306	40
19	0.745687	6	21.2	11	15.80857	2
20	0.607488	26	16.2	41	9.841306	40
21	0.495807	43	23.2	6	11.50273	24
22	0.736306	10	15.2	45	11.19185	28
23	0.495807	43	23.2	6	11.50273	24
24	0.736306	10	15.2	45	11.19185	28
25	0.755414	1	17.6	34	13.29529	11
26	0.72688	15	16.8	37	12.21159	19
27	0.745687	6	17.2	35	12.82582	15
28	0.39244	49	20.6	16	8.08427	45
29	0.365731	51	19.8	19	7.241467	50
30	0.374094	50	20.2	17	7.5567	47
31	0.747397	4	19.6	21	14.64899	5
32	0.72688	15	18.8	26	13.66535	8
33	0.740096	9	19.2	23	14.20985	6
34	0.54412	38	18.7	27	10.17504	38
35	0.553233	37	19.7	20	10.89869	31
36	0.733377	12	18.2	32	13.34746	10
37	0.563006	35	19.1	24	10.75341	34
38	0.563006	35	20.1	18	11.31642	27
39	0.747397	4	18.6	29	13.90159	7
40	0.535424	39	18.3	30	9.798257	42
41	0.535424	39	19.3	22	10.33368	37
42	0.72688	15	17.8	33	12.93847	14
43	0.614627	24	18.7	27	11.49353	26
44	0.605988	29	16.7	38	10.12001	39
45	0.614627	24	21.2	11	13.0301	12
46	0.623809	20	19.1	24	11.91475	21
47	0.623809	20	17.1	36	10.66714	35
48	0.623809	20	21.6	9	13.47428	9
49	0.597701	30	18.3	30	10.93792	30
50	0.597701	30	16.3	40	9.742522	43
51	0.597701	30	20.8	14	12.43218	17

MIX	Extrin @ .7 and .3	Rank	(suitability) Intrin @ Typical	Rank	Multiplic. Result	Rank
1	0.520554	41	25.6	1	13.32618	6
2	0.602426	18	12.6	48	7.59057	48
3	0.581509	30	11.8	51	6.861801	51
4	0.500702	47	24.8	4	12.41741	14
5	0.68704	1	21.6	9	14.84007	1
6	0.602426	18	16.6	39	10.00027	37
7	0.664659	16	20.8	14	13.82491	4
8	0.581509	30	15.8	43	9.187835	44
9	0.520554	41	23.6	5	12.28507	15
10	0.68704	1	15.6	44	10.71783	29
11	0.500702	47	22.8	8	11.41601	24
12	0.664659	16	14.8	47	9.836958	39
13	0.513772	43	25.2	2	12.94705	8
14	0.588415	26	12.2	49	7.178661	50
15	0.595484	23	12.2	49	7.2649	49
16	0.507162	46	25.2	2	12.78049	10
17	0.679619	6	21.2	11	14.40793	2
18	0.588415	26	16.2	41	9.53232	41
19	0.679619	6	21.2	11	14.40793	2
20	0.588415	26	16.2	41	9.53232	41
21	0.513772	43	23.2	6	11.9195	19
22	0.672173	10	15.2	45	10.21702	34
23	0.513772	43	23.2	6	11.9195	19
24	0.672173	10	15.2	45	10.21702	34
25	0.68704	1	17.6	34	12.09191	18
26	0.664659	13	16.8	37	11.16628	26
27	0.679619	6	17.2	35	11.68945	22
28	0.442299	49	20.6	16	9.11135	45
29	0.422002	51	19.8	19	8.355647	47
30	0.42863	50	20.2	17	8.65832	46
31	0.681652	4	19.6	21	13.36039	5
32	0.664659	13	18.8	26	12.4956	13
33	0.675903	9	19.2	23	12.97733	7
34	0.545882	38	18.7	27	10.20799	36
35	0.551567	37	19.7	20	10.86587	28
36	0.670248	12	18.2	32	12.1985	16
37	0.557503	35	19.1	24	10.64832	30
38	0.557503	35	20.1	18	11.20582	25
39	0.681652	4	18.6	29	12.67874	11
40	0.54043	39	18.3	30	9.88986	38
41	0.54043	39	19.3	22	10.43029	32
42	0.664659	13	17.8	33	11.83094	21
43	0.592831	24	18.7	27	11.08594	27
44	0.587043	29	16.7	38	9.803618	40
45	0.592831	24	21.2	11	12.56801	12
46	0.598575	20	19.1	24	11.43278	23
47	0.598575	20	17.1	36	10.23563	33
48	0.598575	20	21.6	9	12.92921	9
49	0.581509	30	18.3	30	10.64161	31
50	0.581509	30	16.3	40	9.47859	43
51	0.581509	30	20.8	14	12.09538	17

MIX	Extrin @ .6 and .4	Rank	(suitability) Intrin @ Typical	Rank	Multiplic. Result	Rank
1	0.535307	41	25.6	1	13.70386	1
2	0.576024	18	12.6	48	7.257908	48
3	0.565757	30	11.8	51	6.675936	51
4	0.5253	47	24.8	4	13.02744	5
5	0.617574	1	21.6	9	13.33961	3
6	0.576024	18	16.6	39	9.562006	39
7	0.607589	16	20.8	14	12.63785	8
8	0.565757	30	15.8	43	8.938965	47
9	0.535307	41	23.6	5	12.63325	9
10	0.617574	1	15.6	44	9.634159	37
11	0.5253	47	22.8	8	11.97684	15
12	0.607589	16	14.8	47	8.992313	46
13	0.531929	43	25.2	2	13.40462	2
14	0.569136	26	12.2	49	6.943456	50
15	0.572557	20	12.2	49	6.985197	49
16	0.528595	46	25.2	2	13.32059	4
17	0.614222	4	21.2	11	13.0215	6
18	0.569136	26	16.2	41	9.219999	44
19	0.614222	4	21.2	11	13.0215	6
20	0.569136	26	16.2	41	9.219999	44
21	0.531929	43	23.2	6	12.34076	11
22	0.610899	10	15.2	45	9.285658	41
23	0.531929	43	23.2	6	12.34076	11
24	0.610899	10	15.2	45	9.285658	41
25	0.617574	1	17.6	34	10.86931	23
26	0.607589	13	16.8	37	10.20749	33
27	0.614222	4	17.2	35	10.56461	27
28	0.495856	49	20.6	16	10.21463	32
29	0.486008	51	19.8	19	9.622962	38
30	0.489252	50	20.2	17	9.8829	35
31	0.613368	7	19.6	21	12.022	14
32	0.607589	13	18.8	26	11.42267	18
33	0.611323	9	19.2	23	11.7374	17
34	0.547553	38	18.7	27	10.23924	31
35	0.549864	37	19.7	20	10.83232	24
36	0.609399	12	18.2	32	11.09106	21
37	0.552286	35	19.1	24	10.54867	28
38	0.552286	35	20.1	18	11.10095	20
39	0.613368	7	18.6	29	11.40864	19
40	0.545356	39	18.3	30	9.98002	34
41	0.545356	39	19.3	22	10.52538	29
42	0.607589	13	17.8	33	10.81508	25
43	0.570138	24	18.7	27	10.66158	26
44	0.567885	29	16.7	38	9.483682	40
45	0.570138	24	21.2	11	12.08692	13
46	0.572511	21	19.1	24	10.93495	22
47	0.572511	21	17.1	36	9.78993	36
48	0.572511	21	21.6	9	12.36623	10
49	0.565757	30	18.3	30	10.35336	30
50	0.565757	30	16.3	40	9.221844	43
51	0.565757	30	20.8	14	11.76775	16

			(suitability)			
MIX	Extrin @ .51 & .49	Rank	Intrin @ Typical	Rank	Multiplic. Result	Rank
1	0.548908	38	25.6	1	14.05204	1
2	0.552966	18	12.6	48	6.967368	48
3	0.551908	24	11.8	51	6.512519	51
4	0.547853	45	24.8	4	13.58676	4
5	0.557038	1	21.6	9	12.03202	9
6	0.552966	18	16.6	39	9.17923	39
7	0.555978	9	20.8	14	11.56434	14
8	0.551908	24	15.8	43	8.720152	43
9	0.548908	38	23.6	5	12.95423	5
10	0.557038	1	15.6	44	8.689794	44
11	0.547853	45	22.8	8	12.49105	8
12	0.555978	9	14.8	47	8.228475	47
13	0.548556	40	25.2	2	13.82361	2
14	0.55226	21	12.2	49	6.737577	50
15	0.552613	20	12.2	49	6.741877	49
16	0.548204	44	25.2	2	13.81475	3
17	0.556684	4	21.2	11	11.80171	11
18	0.55226	21	16.2	41	8.946619	41
19	0.556684	4	21.2	11	11.80171	11
20	0.55226	21	16.2	41	8.946619	41
21	0.548556	40	23.2	6	12.7265	6
22	0.556331	7	15.2	45	8.456232	45
23	0.548556	40	23.2	6	12.7265	6
24	0.556331	7	15.2	45	8.456232	45
25	0.557038	1	17.6	34	9.80387	34
26	0.555978	9	16.8	37	9.340432	37
27	0.556684	4	17.2	35	9.574971	35
28	0.544864	49	20.6	16	11.2242	16
29	0.543812	51	19.8	19	10.76748	21
30	0.544162	50	20.2	17	10.99208	18
31	0.55375	16	19.6	21	10.8535	19
32	0.555978	9	18.8	26	10.45239	26
33	0.554421	15	19.2	23	10.64489	22
34	0.549095	37	18.7	27	10.26808	29
35	0.548385	43	19.7	20	10.80318	20
36	0.555162	14	18.2	32	10.10394	30
37	0.547741	47	19.1	24	10.46186	25
38	0.547741	47	20.1	18	11.0096	17
39	0.55375	16	18.6	29	10.29975	27
40	0.549879	32	18.3	30	10.06279	32
41	0.549879	32	19.3	22	10.61266	23
42	0.555978	9	17.8	33	9.89641	33
43	0.550393	30	18.7	27	10.29236	28
44	0.551114	29	16.7	38	9.203597	38
45	0.550393	30	21.2	11	11.66834	13
46	0.549741	34	19.1	24	10.50005	24
47	0.549741	34	17.1	36	9.400569	36
48	0.549741	34	21.6	9	11.8744	10
49	0.551908	24	18.3	30	10.09992	31
50	0.551908	24	16.3	40	8.996107	40
51	0.551908	24	20.8	14	11.47969	15

			(suitability)			
MIX	Extrin @ Typical	Rank	Intrin @ Typical	Rank	Multiplic. Result	Rank
1	0.713534	15	25.6	1	18.26647	1
2	0.714978	8	12.6	48	9.008728	48
3	0.71603	2	11.8	51	8.449152	51
4	0.714309	9	24.8	4	17.71487	4
5	0.710151	34	21.6	9	15.33927	9
6	0.70924	38	16.6	39	11.77338	39
7	0.711153	25	20.8	14	14.79197	15
8	0.709751	35	15.8	43	11.21406	43
9	0.710476	30	23.6	5	16.76722	5
10	0.712788	16	15.6	44	11.11949	44
11	0.711142	26	22.8	8	16.21403	8
12	0.714035	10	14.8	47	10.56772	47
13	0.713743	12	25.2	2	17.98633	3
14	0.715651	4	12.2	49	8.730945	49
15	0.715283	5	12.2	49	8.726451	50
16	0.71402	11	25.2	2	17.9933	2
17	0.710439	31	21.2	11	15.06131	11
18	0.709478	36	16.2	41	11.49355	41
19	0.710439	31	21.2	11	15.06131	11
20	0.709478	36	16.2	41	11.49355	41
21	0.710648	27	23.2	6	16.48703	6
22	0.713594	13	15.2	45	10.84662	45
23	0.710648	27	23.2	6	16.48703	6
24	0.713594	13	15.2	45	10.84662	45
25	0.715222	6	17.6	34	12.58791	34
26	0.716797	1	16.8	37	12.04219	36
27	0.715707	3	17.2	35	12.31016	35
28	0.711992	23	20.6	16	14.66704	16
29	0.712621	20	19.8	19	14.10989	18
30	0.712379	22	20.2	17	14.39005	17
31	0.70073	50	19.6	21	13.7343	21
32	0.710606	29	18.8	26	13.3594	26
33	0.70368	45	19.2	23	13.51066	23
34	0.71145	24	18.7	27	13.30412	27
35	0.704337	44	19.7	20	13.87544	20
36	0.708184	40	18.2	32	12.88894	32
37	0.704945	43	19.1	24	13.46444	24
38	0.701729	49	20.1	18	14.10476	19
39	0.700554	51	18.6	29	13.03031	31
40	0.71521	7	18.3	30	13.08835	29
41	0.710439	33	19.3	22	13.71147	22
42	0.712593	21	17.8	33	12.68415	33
43	0.705602	41	18.7	27	13.19475	28
44	0.70902	39	16.7	38	11.84063	38
45	0.705602	41	21.2	11	14.95876	13
46	0.702531	46	19.1	24	13.41834	25
47	0.702531	46	17.1	36	12.01328	37
48	0.702531	46	21.6	9	15.17466	10
49	0.712772	17	18.3	30	13.04373	30
50	0.712772	17	16.3	40	11.61819	40
51	0.712772	17	20.8	14	14.82566	14

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Vita

Captain Paul G. Filcek graduated from Mio AuSable High School, Michigan, in May 1983.

He enlisted in 1984 as an Aircraft Maintenance Technician, attaining the rank of master sergeant during a 12-year enlisted career, with assignments at Reese AFB, Texas; Osan AB, Korea; Myrtle Beach AFB, South Carolina; and Randolph AFB, Texas. He was decorated for action during Operations DESERT SHIELD and DESERT STORM, earned the Humanitarian Service Medal, and earned Numbered Air Force-level NCO of the Quarter Awards, the NCO of the Year, and nomination for the Lt Gen Leo Marquez Award. He also garnered the Commandant's Award from the Command NCO Academy.

Captain Filcek earned an Associates of Applied Science degree in Aircraft Technology from the Community College of the Air Force in 1994, going on to graduate with a Bachelor of Science degree in Occupational Education from Wayland Baptist University in 1996. He was commissioned through Officer Training School in 1997.

He was assigned to Davis-Monthan AFB, Arizona that same year. He was decorated, and won the CGO of the Year Award, for his numerous deployments as the Squadron Maintenance Officer supporting the 42d Airborne Command and Control Squadron's combat operations over Kosovo and Bosnia-Herzegovinia for NATO Operations DELIBERATE GUARD, DELIBERATE FORCE, and ALLIED FORGE. In August 2000, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduation, he will be assigned to Scott AFB, Illinois. Captain Filcek is married to Kil Pae Filcek. They have one daughter, Kimberly.

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14. ABSTRACT Selection of combat aircraft during crisis action planning can be of critical importance. In determining the value of force mixes, it is proposed that one can evaluate extrinsic and intrinsic value separately. Intrinsic value is the designed capability of a weapons platform to accomplish a specified aerospace mission. Extrinsic value is the expected appropriateness of such platforms, given the environmental characteristics in which they must operate. This research develops a decision support tool for planners in determining the extrinsic value of force mixes, which then expedites the selection of best overall force mixes. The research included: content analysis of official guidance, Critical Decision Methodology interviews, a Delphi study (to define and quantify the factors, and establish a hierarchy and global weights), generation of the Value Focused Thinking decision tool, and establishment of an appropriate relationship between extrinsic and intrinsic value. This research provides planners—throughout the USAF—with a decision support tool that objectively compares alternative force packages for specific deployments. This represents a first step toward codifying or formalizing the art of force selection. These results will help reduce the crisis action response timeline, and should lead to more accurate modeling of force mix applicability.

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